GENERAL LIBRARY
MAR 11 1919
UNIV. OF MICH.
Engineering Library

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CVII.—No. 2772.] *LONDON: FRIDAY, FEBRUARY 14, 1919.* [*Registered at the General Post Office as a Newspaper.*] [PRICE 9d. BY INLAND POST ... 11d.

Aveling & Porter, Ltd.,
ROCHESTER, KENT.
and 72, CANNON STREET, LONDON.
STEAM ROLLERS. ROAD LOCOMOTIVES.
STEAM CULTIVATING MACHINERY.
STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 6808

A. G. Mumford, Ltd.,
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See Advertisement, page 33.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

Henry Butcher & Co.,
VALUERS AND AUCTIONEERS
to the
ENGINEERING, FOUNDRY, & METAL TRADES.
ALSO FOR
PLANT AND MACHINERY. 6398
63 and 64, CHANCERY LANE, W.C. 2.

Cranes.—Electric, Steam,
HYDRAULIC and HAND.
of all types and sizes.
GEORGE RUSSELL & CO., LTD.,
Motherwell, near Glasgow. 7264

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 7410
See Advertisement last week, page 131.

Plenty and Son,
LIMITED.
MARINE ENGINEERS, &c.
NEWBURY, ENGLAND. 9083

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD.,
ENGINEERS, NEWCASTLE-ON-TYNE. 7260

Ball Bearings
Always British Large Sizes.
BLACKSTOCK BALL BEARING CO.,
London Office:—304, High Holborn, W.C. 1.
For Illustrated Advertisement, see page 6. 7356

For High-class Castings in
Gun-metal, Phosphor and Manganese Bronze, White Metal and other Alloys, up to 3 cwts.
JOHN CLIFFE, Chemist and General Founder, Great Brook Street, Birmingham. 7127

"Spencer-Hopwood" Patent Boilers.
Sole Makers:
W. H-SPENCER & CO., HITCHIN, HERTS.
See page 10

Invincible Gauge Glasses.
BUTTERWORTH BROS., Ltd.,
Newton Heath Glass Works,
Manchester. Od 975

S. H. Heywood & Co., Ltd.,
REDDISH. 7182
ELECTRIC TRANSPORTERS.

Fuller, Horsey, Sons & Cassell,
SPECIALISTS
in the
SALE AND VALUATION
of
PLANT AND MACHINERY 1634
and
ENGINEERING WORKS.
11, BILLITER SQUARE, E.C. 3.

Iron and Steel
Tubes and Fittings.
6920
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 99, Feb. 7.

Yarrow & Co., Ltd.,
SHIPBUILDERS AND ENGINEERS,
GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF
EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast
by YARROWS, LIMITED, Victoria, British Columbia, 6876
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
Gear Cutting.
Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

Yachts, Launches, or Barges,
Built complete with Steam, Oil or Petrol Motors, ; or Machinery supplied. Od 3561
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO.,
50, Wellington Street, Glasgow. 6961

Oil Fuel Appliances.
SYSTEMS { PRESSURE, AIR, STEAM.
FOR BOILERS OF ALL TYPES.
Kermodes Limited,
35, THE TEMPLE, DALE STREET, LIVERPOOL;
and
109, FENCHURCH STREET, LONDON. 4078
NAVAL OUTFITS A SPECIALTY.

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED,
Boyne Engine Works, Leeds. Od 2437
See their Illus. Advertisement, page 141, last week.

Cochran MULTITUBULAR AND CROSS-TUBE TYPES.
Boilers.
See page 125. 7263
RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS,
MOTHERWELL. Od 3383

Henry Wells Oil Co.,
11, HAYMARKET,
London, S.W. 1.

"Aptol" Lubricants.
WORKS: SALFORD, MANCHESTER. 7184

S. H. Heywood & Co., Ltd.,
REDDISH. 7182
ELECTRIC LIFTS (UP TO 35 TONS).

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 7312

New Chicago Automatics,
Three Sizes, Delivery from Stock.
NEW CAPSTANS, 1¼ in. through the wire feed.
JOHN MACNAB, MARY STREET, HYDE.
Tel. No.: 78 Hyde. 6874

John Bellamy, Limited,
MILLWALL, LONDON, E. 1316
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Tubes and Fittings.
Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 126. 7268

Rubber MANUFACTURERS
Belting
GUTTA PERCHA & RUBBER, LIMITED
Toronto - - Canada. 6702

CO_2 Plants (CARBON DI-OXIDE)
for Chemical Wks., Mineral Water Mfrs., Breweries, and all other purposes.—READ & CAMPBELL, Ltd., 109, Victoria St., S.W. 1 ("Valorem, London.").

B.F.A. Fire Extinguishers
are foremost as fire fighters. No Acids. No Alkalis. Safe to use and always ready.—BRITISH FIRE APPLIANCES CO., Ltd., 109, Victoria St., London, S.W. 1.

Crittall. Crittall.
CHEMICAL ANALYSIS
Physical Tests.
Microscopical Examinations.
Heat Treatment & Pyrometer Tests.
Critical Range Determinations.
SCALE OF FEES ON APPLICATION.
THE CRITTALL MANUFACTURING CO., LTD., BRAINTREE, ESSEX.
Chief Metallurgist, H.S. PRIMROSE.
Crittall. Crittall. 6966

CHANTIERS & ATELIERS
Augustin - Normand
67, rue de Perrey—LE HAVRE
(France).
Destroyers, Torpedo Boats, Yachts and Fast Boats. Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines. 8300

S. H. Heywood & Co., Ltd.,
REDDISH. 7182
ELECTRIC CRANES.

A Time Recorder, as New,
guaranteed, latest model. WHAT OFFERS?—A. G. PELLEY, 149, Farringdon Road, E.C. 1. G 156

Gas and Oil Engine Repairs.
—E. J. DAVIS & CO., Great Eastern Road, Stratford, E. 15.
Tel.: 736 and 737 Stratford.
Gram.: Rapidising, London. 1794

R. Y. Pickering & Co., Ltd.,
(ESTABLISHED 1864.)
BUILDERS of RAILWAY CARRIAGES & WAGONS.
MAKERS of WHEELS and AXLES of all kinds.
RAILWAY WAGONS FOR HIRE.
Chief Works and Offices:
WISHAW, near GLASGOW.
London Office:
5, VICTORIA STREET, WESTMINSTER, S.W. 8353

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS,
CONDENSERS, AIR HEATERS,
STEAM AND GAS KETTLES. } Row's Patents
Merrill's Patent TWIN STRAINERS
for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES.
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 6738

Yarrow Patent Water-tube Boilers. 6877
MESSRS. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton.** 6054
See Full Page Advt., page 78, Feb. 7.

Forgings.
Walter Somers & Co., Ltd.,
HALESOWEN. 6849

"Delta" Brand HIGH-CLASS ENGINEERING ALLOYS.
Forgings, Castings, Bars, Sheets, Wire, Tubes.
THE DELTA METAL CO., LTD., 6963
H. GREENWICH, LONDON, S.E. 10 (& at Birmingham.

Taylor & Challen Presses. 8195
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement Feb. 7.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED,
DARLINGTON. 6974

Cement.—Maxted & Knott,
LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest references. Established 1900.
Address, BURNETT AVENUE, HULL.
Cablegrams: "Energy, Hull." 6200

Machine and Engineering
WORK of all description undertaken for Manufacturers, Patentees, &c. Also repairs and renewals. Best work moderate charges.—ROSS & HUSSELL, LTD., Queen's Wharf, Hammersmith.
NEW PATENT ACT.—ROSSER & RUSSELL, Ltd., are prepared to undertake the manufacture of articles as presents made abroad, and will be pleased to hear from firms desiring such work executed. 9211

S. H. Heywood & Co., Ltd.,
REDDISH. 7182
LOCOMOTIVE TRAVERSERS (ELECTRIC).

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, GLASGOW. Od 6547
Registered Offices: 108A, Cannon St., London, E.C.

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7006
See half-page Advertisement page 56, Jan. 24.

The Manchester Steam Users' Association.

For the Prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. B. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 6661

Royal Show, Cardiff.

JUNE 24th to JUNE 28th, 1919.

IMPLEMENTS.

The Regulations and Forms of Application for Space are now ready.

Applications must be made by THURSDAY, MARCH 20th, 1919.

Live Stock Entries close on MAY 20th; Poultry, Rabbits, Produce and Flower Show on MAY 31st; Cider and Perry Entries close on MAY 1st.

THOMAS McROW, Secretary.

ROYAL AGRICULTURAL SOCIETY OF ENGLAND,
16, Bedford Square, London, W.C. 1.
January 1919. S 783

ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.

CENTRAL LONDON SUB-BRANCH.

The Quarterly Meeting of

MEMBERS will be held at the CENTRAL HALL, WESTMINSTER, S.W. 1, on FRIDAY, 21st FEBRUARY, at 7.30 p.m. prompt.

Business of great importance will be brought forward, and all members are specially requested to be present.

Particulars of the Association can be obtained from the Recruiting Secretary, Mr. A. KEY, 129, The Grove, W. 6. S 636

M. R. DEWHURST,
Hon. Secretary.

University of Liverpool,

SESSION 1918-19.
FACULTY OF ENGINEERING.
Dean—Associate Professor J. WEMYSS ANDERSON, M.Eng., M.Inst.C.E.

Prospectuses and full particulars of the following may be obtained on application to the REGISTRAR: Engineering, Electrical Engineering, Civil Engineering, Naval Architecture, Marine Engineering, Engineering Design and Drawing, and Refrigeration, Mathematics, Physics, Chemistry. S 593

Northampton Polytechnic

INSTITUTE.
St. John Street, Clerkenwell, E.C. 1.

Principal—R. MULLINEUX WALMSLEY, D.Sc.

A SPECIAL COURSE of Practical Instruction, extending over twelve weeks, will be given in Oxy-Acetylene Welding, on Monday, Wednesday and Friday evenings, from 7.0 to 9.30, commencing on the 17th inst. Fee for the course £1. S 598

Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—30, Victoria St., Westminster, S.W. 7438

Engineering Special Classes.

Marine & Aero Engines, Alternating Currents, Wireless Course, Ferro-Concrete, Refrigeration, Pract. Maths. and Calculus.—PENNINGTONS, University Tutors, 264, Oxford Rd., Manchester.

Inst. C.E., Inst. Mech. E.,

and all Engineering Exams. Correspondence coaching by practical engineers. I.C.E. successes 265 out of 294. Two Baylis Prizes, "Proxime Accessit." Special features for foreign candidates. Write for book 1-6, &c.—Address, 7434, Offices of ENGINEERING.

Members of Institutions can

have their PAPERS or LECTURES DELIVERED effectively by experienced Public Reader (Engineer).—S 380, Offices of ENGINEERING.

Reconstruction. — Firms Re-

QUIRING experienced and competent MANAGERS or FOREMEN are requested to communicate with the SECRETARY of the COVENTRY FOREMEN'S ASSOCIATION OF ENGINEERING & ALLIED TRADES, LTD., at No. 7, The Quadrant, Coventry. S 612

TENDERS.

CITY OF BIRMINGHAM.

TRAMWAYS DEPARTMENT.

ELECTRIC TRAMWAY CARS.

The Tramways Committee are prepared to receive—

Tenders for the Supply,

DELIVERY, and ERECTION OF ADDITIONAL ROLLING STOCK.

A Form of Tender, with instructions, general conditions, specification and drawings can be obtained on application to the undersigned at the Tramway Offices, The Council House, Congreve Street, Birmingham, on payment of £2, which will, after the Committee shall have come to a decision upon the tenders received, but not before, be returned to the tenderer, provided he shall have sent in a bona fide tender.

Persons Tendering must at the time of Tendering and at all times during the execution of the work be paying all their workpeople (except such as may be employed under special provisions agreed upon by the employers and the local organised bodies of workers) not less than the Trade Union or Standard Rate of Wages in the several districts where the work people are actually engaged in the execution of the works, and must also be observing the hours and conditions of labour, as well as the aforesaid rate of wages, recognised by the Associations of Employers and the Local Organised Bodies of Workers in the various trades in the several districts where the works are being done. The Tender of any Contractor who does not pay the Trade Union or Standard Rate of Wages or observe similar conditions in his ordinary business will not be accepted.

Tenders must be enclosed in a sealed cover, addressed to the CHAIRMAN OF THE TRAMWAYS COMMITTEE, The Council House, Congreve Street, Birmingham, and endorsed in the left hand corner, "Tender for Rolling Stock," and must be handed in not later than Ten o'clock on Wednesday, the 5th March, 1919.

The Tramways Committee do not bind themselves to accept the lowest or any tender.

ALFRED BAKER,
General Manager.

Tramway Offices,
The Council House,
Congreve Street,
Birmingham. S 465

MINISTRY OF MUNITIONS, IRELAND.

DUBLIN NATIONAL SHELL AND FUSE FACTORIES.

WATERFORD NATIONAL CARTRIDGE FACTORY.

CORK NATIONAL SHELL FACTORY.

GALWAY NATIONAL SHELL FACTORY.

It is notified that

Offers for the Plant,

MACHINE TOOLS, EQUIPMENT, &c., of the above-mentioned Factories should be made to the DIRECTORS, MINISTRY OF MUNITIONS, 32, Nassau Street, Dublin, not later than the 20TH FEBRUARY, 1919. S 725

APPOINTMENTS OPEN.

ROYAL TECHNICAL INSTITUTE, SALFORD.

Principal—B. PRENTICE, D.Sc., Ph.D.

Lecturer in Electrical Engi-

NEERING WANTED, to commence March 1st. Engineering degree and works experience essential. Salary according to scale and teaching experience.—Particulars and forms of application may be obtained from the SECRETARY to the Education Committee, Education Office, Chapel Street, Salford, and must be returned not later than February 19th. S 501

L. C. EVANS, Town Clerk.

HULL EDUCATION COMMITTEE.

MUNICIPAL TECHNICAL COLLEGE.
Principal, MR. T. LUXTON, B.A., B.Sc. (Lond.).

ASSISTANT LECTURER ON ENGINEERING.

An Assistant Lecturer on

ENGINEERING is REQUIRED for the above College. Hons. Degree requisite. Salary £250, rising to £350, with additional payment for Evening Classes. Commencing salary according to experience.

Forms of application may be obtained from the undersigned on receipt of a stamped addressed foolscap envelope, and must be returned so as to reach these offices not later than the 21st February, 1919.

J. T. RILEY,
Director of Education.

Education Offices,
Albion Street, Hull.
3rd February, 1919. S 541

UNIVERSITY COLLEGE, NOTTINGHAM.

LECTURER IN ELECTRICAL ENGINEERING.

The Council of the College invite

Applications for the Post of

SENIOR LECTURER in Electrical Engineering, commencing salary £300 per annum.

Further particulars and application forms may be obtained from the REGISTRAR, to whom applications must be sent not later than 3rd March. S 568

Wanted, Assistant Buyer for

large Electrical Engineering Company, previous experience essential.—State full particulars and salary required to "BUYER," care of W. H. SMITH & SON, Advertising Agents, Blackfriars, Manchester. S 529

Chief Turbine Designing En-

GINEER REQUIRED, Manchester district. Must be thoroughly experienced in Impulse Turbines and Rotary Blowers. Only first-class men with sound experience in above need apply.—Address, stating age, full experience and salary required, S 543, Offices of ENGINEERING.

Metallurgical Chemist

REQUIRED by Motor Car and Aero Engine Manufacturers. Chemist with practical knowledge and experience of carbon and alloy steels, heat-treatment, non-ferrous alloys, physical testing and metallography. Give full particulars, age, experience, etc., to S 594, Offices of ENGINEERING.

Required for Large Combined

Shipbuilding and Engineering Works on N.E. coast, England, SHIPYARD MANAGER. Must be fully qualified in practical knowledge and conversant with handling of working arrangements with employees and all Federation and Association business. Opportunity of future advancement for suitable applicant.—Address, S 633, Offices of ENGINEERING.

Engineer Wanted for Factory

near Bristol, to take charge of plant of moderate size, acquainted with steam and electric power and steam boiling vessels, pumps, etc. Drawing office experience desirable.—State age and salary required, to S 630, Offices of ENGINEERING.

Assistant Required in Esti-

mating Department of large general Engineering Firm in the Eastern Counties.—Address, stating age, experience and salary required, S 627, Offices of ENGINEERING.

Steel Foundry Manager

REQUIRED for a large works in South Midlands. Must have exceptional all-round experience of high-class steel castings, electric furnace, converters and Siemens-Martin. Output bonus paid.—Address, stating salary required and full particulars, S 628, Offices of ENGINEERING.

A Company Manufacturing

Electrical Speciality for use on Railways, REQUIRES the services of a SALESMAN ENGINEER to extend their sales. Applicants must have good connection and should state their knowledge of Railway working and Officials and salary required, to S 631, Offices of ENGINEERING.

Costing and Estimating Clerk

REQUIRED for General Engineering Works, must be able to take out quantities from drawings. Address, giving full details of qualifications, age and salary required, S 710, Offices of ENGINEERING.

Rolling Mill Engineer

REQUIRED by progressive Rolling Mill makers. Gentleman with intimate knowledge of design of Rolling Mills, capable of estimating, interviewing and generally taking over the design and sales department.—Address, S 764, Offices of ENGINEERING.

Works Manager Wanted for

Engineering Works in South of England, producing Small Oil Engines and other Repetition Work. Only men thoroughly experienced in Modern Machine Tool Practice, and in fixing Piece Work Prices need apply. Excellent opening for first rate man, with good organising ability. State experience, age, and salary required.—Address, S 729, Offices of ENGINEERING.

Constructor, Highly Experi-

enced (age immaterial) WANTED, also several neat TRACERS for Woodworking Machines, also Labour-saving Machine Tools. Well-paid, progressive position. South of England.—Address, in confidence, with full particulars as to experience, references, salary, S 730, Offices of ENGINEERING.

Engineer Wanted for Wire-

Drawing Plant. Must be thoroughly conversant with the whole running of a wire-drawing plant for the manufacture of all sorts of wire used in wire-rope making, required to take charge of factory abroad.—Write, stating experience to Z. R. 513, care of DEACON'S, Leadenhall Street, London, E.C. 3. S 744

Reconstruction in France.—

WANTED immediately, a Competent ENGINEER, to represent in Paris the interests of a Leading Firm of English Contractors. It is essential that applicants should not only be qualified to carry out and direct Works of Construction, but should be of good appearance and address, capable of conducting negotiations and a fluent French scholar.—Write giving age and full particulars of qualifications and last experience to BOX 721b, SMITH'S, 21, Bush Lane, London, E.C. 4. S 772

Wanted for an Indian Railway,

TWO Young ASSISTANT ENGINEERS of good technical education and some experience (not necessarily in India) of maintenance and construction. Write to B. A. R., care of STREET'S, 30, Cornhill, E.C. 3, stating school and subsequent technical training. S 602

NOTICE.

BOMBAY MUNICIPALITY.

Applications are Invited for

the POST of ASSISTANT ENGINEER, ROADS, in the Public Works Department of the Bombay Municipality.

(2) Applicants should have had at least 15 years experience in road construction and maintenance with various materials and should have held an appointment as Chief Surveyor, with the control and direction of large bodies of workmen. They should be experienced in quarrying operations preferably in trap rock, have knowledge of stone sett and wood paving, have practical experience of tar and bituminous construction work, and fully understand the use and application of the relative mechanical appliances.

(3) The duties of the post will consist chiefly in organizing labour, in guiding and training the staff in modern scientific methods, and in closely supervising the construction of, and repairs to, all Roads and Streets within the jurisdiction of the Municipality and under the direction of the Executive Engineer.

(4) Preference will be given to candidates who have qualified as Members of the Institute of Civil Engineers or of the Municipal and County Engineers and who have had experience of Road Board Work.

(5) Age should be between 30 and 45 years.

(6) The appointment has been sanctioned provisionally for a period of five years at a salary of Rs. 800/- per mensem rising to Rs. 1,000/- per mensem by annual increments of Rs. 50/-. A conveyance allowance of Rs. 100/- per mensem is attached to the post.

(7) The successful candidate will be required to produce a certificate (from a competent source) of fitness for service in the tropics.

(8) The successful candidate, if appointed in India will be allowed first class railway fare to Bombay, and if appointed from the British Isles a first class free passage out to Bombay with full pay during the voyage.

(9) One month's privilege leave for every 11 months' active service subject to a maximum of 3 months at one time will be allowed.

(10) Applications with one copy each of three recent testimonials should be addressed to the Undersigned and should reach him not later than 15th April, 1919. Applicants should state the earliest date on which they can take up the appointment after receiving intimation of appointment.

JAMES W. MACRISON,
B.Sc., M.Inst.C.E.,
Executive Engineer,
Bombay Municipality.

Municipal Offices, Bombay,
9th January, 1919. S 459

Wanted at Once for a

Colliery in the Midlands, ELECTRICIAN, used to alternating current, and mixed pressure turbine.—Address, S 721, Offices of ENGINEERING.

A Large Firm of Engineers

in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4359, Offices of ENGINEERING.

Old-Established Firm of Old

METAL DEALERS in the North of England, with well equipped premises, REQUIRE the services of a CAPABLE MANAGER.—Write, stating age, qualifications and salary required, to K. A., care of J. W. VICKERS & Co., LTD., 5, Nicholas Lane, E.C. 4. S 753

Wanted, Qualified Electrical

ENGINEER to take charge of large Shipyard installation on East Coast of Scotland, comprising 3000 kilowatts alternating and direct current motors, and lighting, supply from two sub-stations with rotary converters and tran-formers. Applicants should be thoroughly conversant with power installations on A.C. and D.C. systems, and be capable of carrying out extensions if required. Preference will be given to applicant with experience in shipyard power work. Permanent situation to suitable man.—Applications giving full particulars as to age, experience, and salary required, with copies (only) of testimonials, to be forwarded to S 669, Offices of ENGINEERING.

Wanted, Works Manager

(full shop hours) for engineering works in N.W. of England, employing 200 hands on very varied output, including boiler work. State age and qualifications. Commencing salary £500.—Address, S 474, Offices of ENGINEERING.

Manager Required for Boiler-

works employing 100 hands, progressive opening for an experienced man, could take financial interest later if desired. Only applicants having held similar appointment need apply, stating age, experience and salary required, to THE FARRAR BOILERWORKS, LTD., Newark-on-Trent. S 472

Required, for large combined

Shipbuilding and Engineering Works on N.E.C. England, SHIPYARD MANAGER. Must be fully qualified in practical knowledge, and conversant with handling of working arrangements with employees and all Federation and Association business. Opportunity of future advancement for suitable applicant.—Address, S 357, Offices of ENGINEERING.

Old-established Engineering

Firm, manufacturing a speciality in great and increasing demand, requires the services of a gentleman to organize and take charge of Colonial and Foreign sales department. Must be experienced in arranging Agencies and have travelled. Substantial position for suitable man.—Address, S 262, Offices of ENGINEERING.

Good Opening Occurs for a

young man as PROGRESS CLERK in connection with the mass production of medium-size engineering articles in a modern Works in Leicestershire. Only those with considerable experience of work in connection with the Progress records of repetition work need apply. State age, experience, and class of work previously engaged on, and when disengaged, in first instance.—S 244, Offices of ENGINEERING.

Wanted, Engineer to Take

FULL CHARGE of a large establishment manufacturing Enamelware in Italy. Experience and knowledge of French or Italian is essential, and must have a thorough understanding of the use of chemicals, plant, &c., employed, in this industry.

For further particulars, write to
E. ROBINSON & CO., S 668
5, Gloucester Mansions, Cambridge Circus, W.C. 2.

Wanted, an Assistant Esti-

MATOR with technical experience in engines and turbines. Please state age, experience and salary. Application will be considered confidential. —Address, "TECHNICAL," WM. PORTEOUS & Co., Advertising Agents, Glasgow. S 361

Outside Representative.—

Messrs. THWAITES BROTHERS, LTD., Bradford, REQUIRE the SERVICES of an energetic and well-trained ENGINEER, having, for preference, some experience in Iron and Steel Foundry Plants, comprising converters, cupolas and blowers, as OUTSIDE REPRESENTATIVE and TRAVELLER. Applications from purely commercially trained men will not be considered. Applicants must have had works' experience. Good salary and permanent position to suitable man. Applications in the first case must be in writing addressed to the firm, and should state experience and salary required. S 426

Clerk of Works or Engineer

WANTED, to superintend the erection of new extensions to large Engineering Works in the North of England.

Applicants should preferably have had experience in the laying out of modern Engineering Works, and a knowledge of the best practice in heating, lighting and ventilating.

Engagement to close on completion of Contracts. Full particulars and salary required, to S 614, Offices of ENGINEERING.

Works Manager Wanted by

an engineering firm in Scotland with about 1800 employees and manufacturing heavy and medium engines, pumps and other specialities.

Only those with successful management experience in modern machine shops and in foundry practice (including repetition work) need apply.

State age, qualifications, and salary required to S 641, Offices of ENGINEERING.

Constructional Engineer in

the Manchester District REQUIRES services of GENERAL FOREMAN, who must be thoroughly practical, accustomed to up-to-date methods and the management of men. Very good salary and Bonus will be paid.—Apply by letter, stating age and reference, to S 648, Offices of ENGINEERING.

DOUBLE-REDUCTION GEARED TURBINE MACHINERY FOR THE S.S. "MERIDA."

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

(*For Description, see Page* 207.)

Fig. 3.

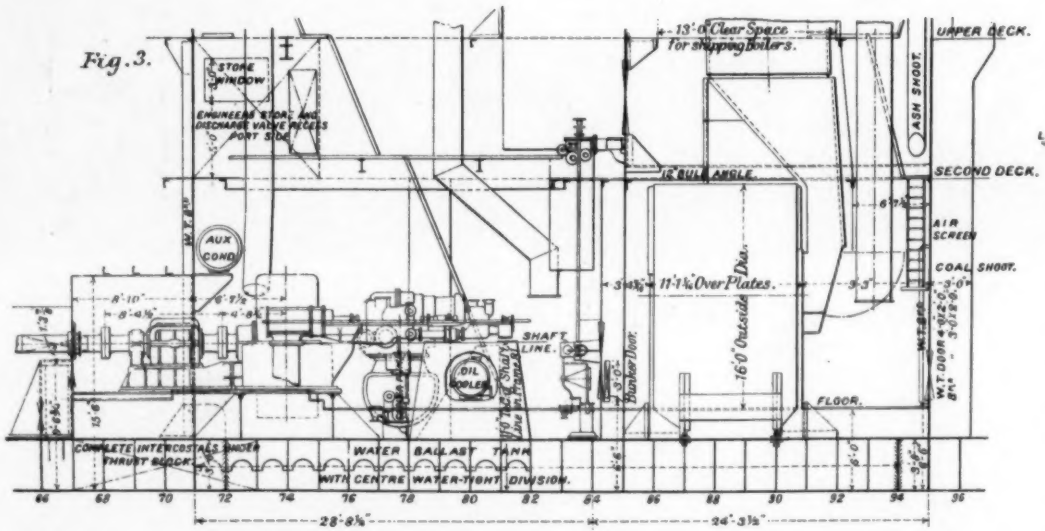
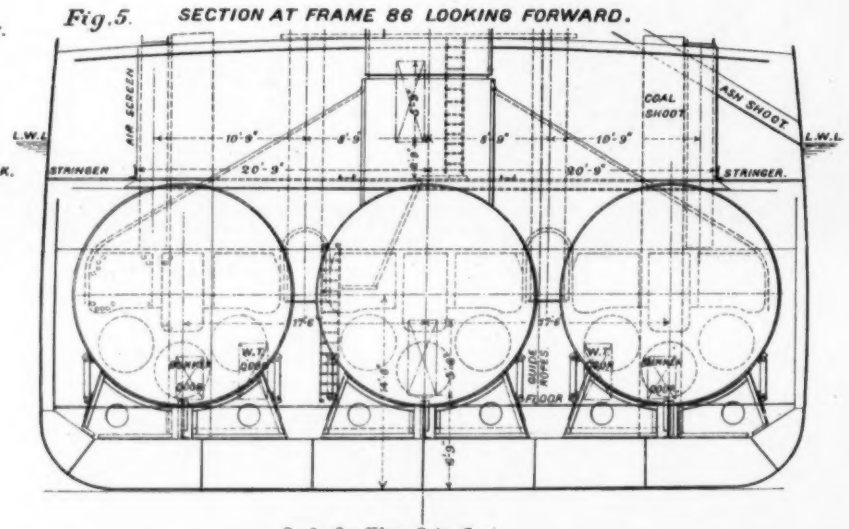


Fig. 5. SECTION AT FRAME 86 LOOKING FORWARD.



Scale for Figs. 3 to 6.

0 10 20 30 40 Feet.

Fig. 4.

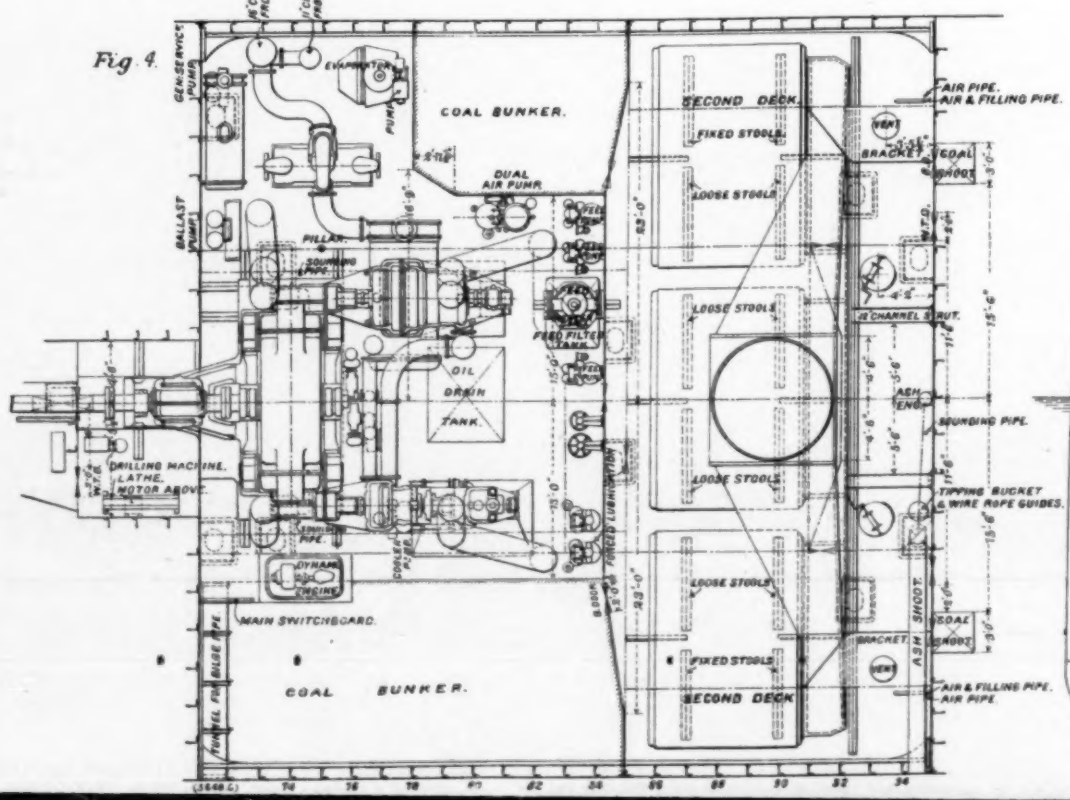


Fig. 6. SECTION AT FRAME 80 LOOKING AFT.

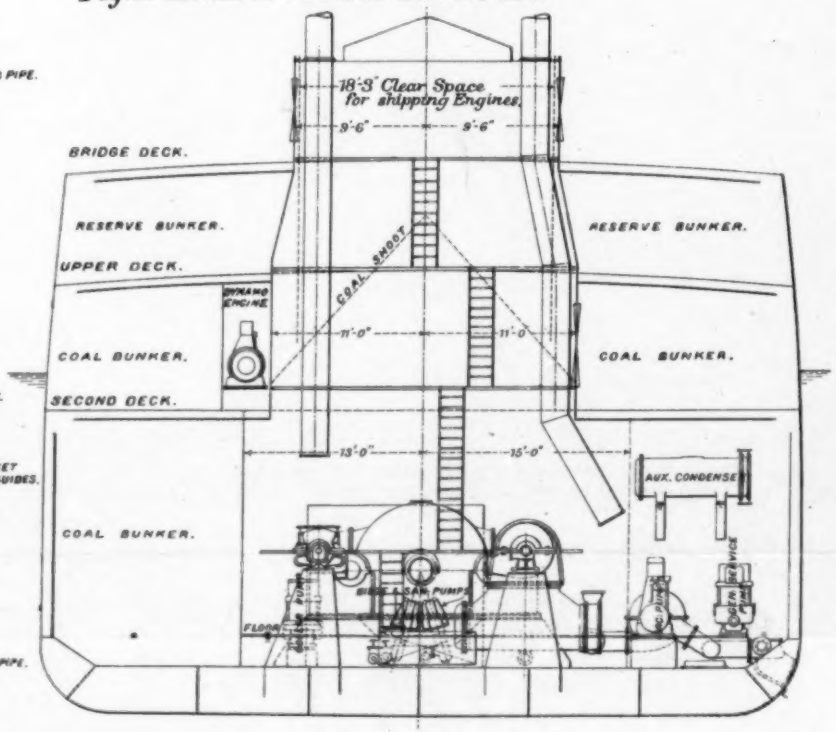


Fig. 4.

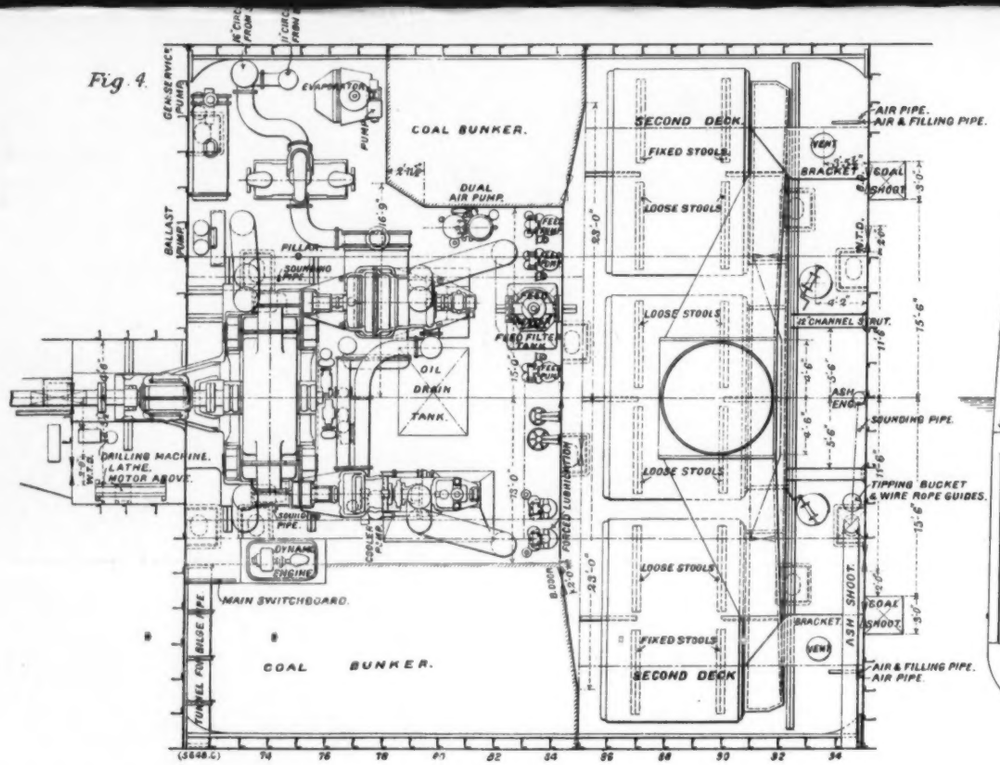


Fig. 6. SECTION AT FRAME 80 LOOKING AFT.

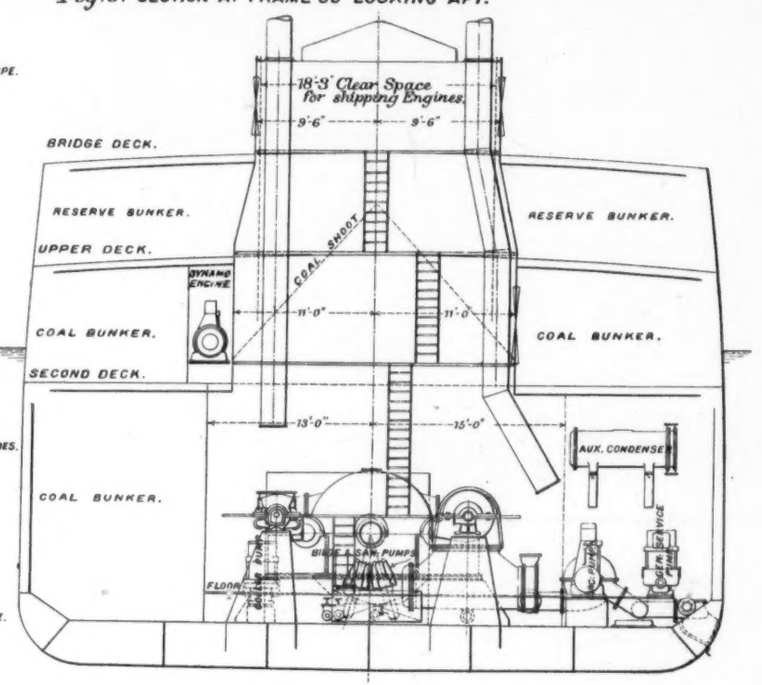


Fig. 7.

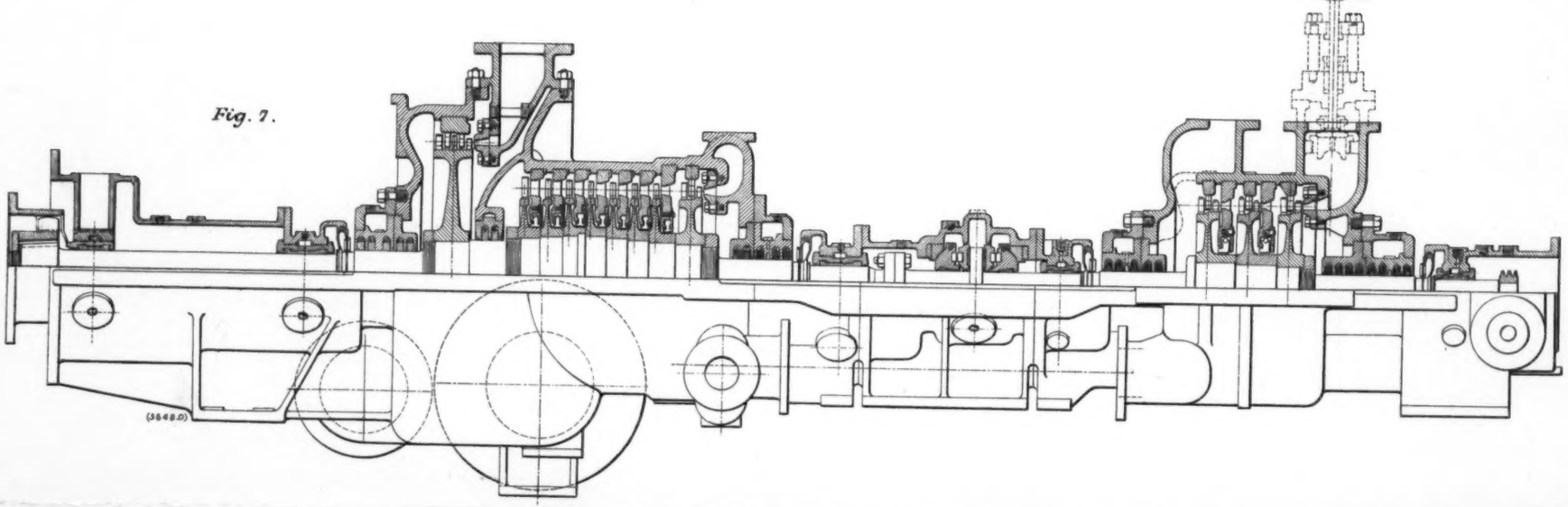
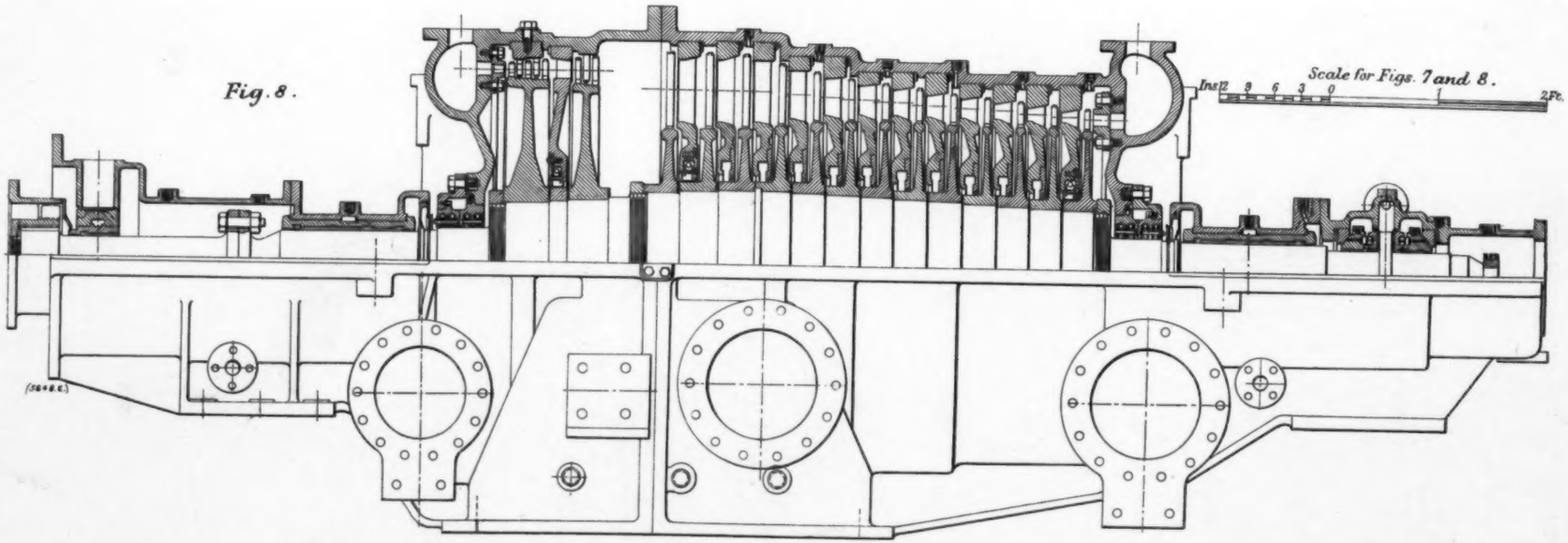


Fig. 8.



TORSIONAL LOADS IN THE FUSELAGE OF AN AEROPLANE.

By A. J. SUTTON PIPPARD, M.Sc., F.R.Ae.S.

1. *General.*—A fuselage may be subjected to air loads which tend to twist it about a longitudinal axis either through unequal loading on the port and starboard sides of the tail plane or through the fin and rudder loads being offset from the axis. In order to design a suitable structure it is necessary to know how these external loads are transmitted through the bracing. In calculations upon the torsional rigidity of a fuselage also it is essential to know the stiffness of the structure, i.e., the angular distortion under torque. If a complete fuselage is available the best method of obtaining this latter figure is by direct measurement, but in most cases this is not practicable, and the designer must have recourse to calculation. Many methods of calculation have been advanced, but the one given in this article is easy to use and has the advantage that much of the work is done on the drawing board.

2. *Assumptions.*—In investigating a problem of this kind it is necessary to make certain assumptions, and these must be clearly borne in mind when applying the results. Such assumptions are as follows :—

First, the whole of the deformation of the fuselage is supposed due to the stretch of the panel bracing wires. The compression of the wooden members is small compared with this, and it is sufficiently accurate to ignore such compression. A slight extension of the work, however, will include its effect if a further degree of accuracy is required.

Secondly, the bulkhead bracing wires are considered to be inoperative. This at first appears rather unjustifiable, especially as these wires are often referred to as torsion wires, but observation of many tests shows that this is a perfectly sound assumption.

Thirdly, it is assumed that the cross-section of the fuselage is everywhere rectangular.

Fourthly, the fittings are supposed to be of such a type that they do not slide along the longerons under a load.

3. *Method of Solution.*—Consider a fuselage as shown in Fig. 1 to be supported at the centre section A B C D, and to be under a torque $= \mu$ at the end.

The torque may be resolved into two couples consisting of P P and Q Q acting in the planes of the top and bottom, and the side panels respectively.

Then

$$P d + Q b = \mu \quad . \quad . \quad . \quad (1)$$

where d is the depth of the fuselage and b the breadth at the end section.

It is clear that P and Q can be given an infinite number of values satisfying the equation (1), but if the correct ones can be found our problem is solved. Assume then that P and Q are the required forces. P and Q will be such that the work stored in the structure will be a minimum.

Considering the top face of the fuselage it is evident that the bracing wires are stressed by the load P.

Let the length of any wire be l.

Let the load in this wire be k P.

Let the cross-section of the wire be a.

Let the modulus of elasticity of the wire $=$ E.

Then the extension of the wire will be :

$$\frac{k P l}{a E}$$

and the work done on the wire in stretching it will be :

$$u_l = \tfrac{1}{2} k P \times \frac{k P l}{a E}$$

$$u_l = \frac{k^2 P^2 l}{2 a E}$$

∴ The total work done in stretching the whole of the top panel bracing wires is :

$$U_T = \frac{P^2}{2 E} \Sigma \frac{k^2 l}{a}$$

Put :

$$\frac{k^2 l}{a} = x$$

so that :

$$U_T = \frac{P^2}{2 E} \Sigma x \quad . \quad . \quad . \quad . \quad (2)$$

In the bottom panel bracing the opposite diagonal wires are stretched ; so if k_1, l_1 and a_1 represent corresponding values to k, l and a for the top panels, then the total work done on the bottom panel wires will be :

$$U_B = \frac{P^2}{2 E} \Sigma \frac{k_1^2 l_1}{a_1}$$

Put

$$\frac{k_1^2 l_1}{a_1} = x_1$$

so that :

$$U_B = \frac{P^2}{2 E} \Sigma x_1 \quad . \quad . \quad . \quad (3)$$

Now, considering the side panels :—

Let K Q and K_1 Q be the loads in a port and starboard wire respectively.

Let L and L_1 be the lengths of these wires.

Let A and A_1 be the cross-sectional areas of these wires.

Let U_P and U_S be the total work done on the wires of the port and starboard sides respectively.

Then putting :

$$\frac{K^2 L}{A} = X \text{ and } \frac{K_1^2 L_1}{A_1} = X_1$$

we have :

$$U_P = \frac{Q^2}{2 E} \Sigma X \quad . \quad . \quad . \quad (4)$$

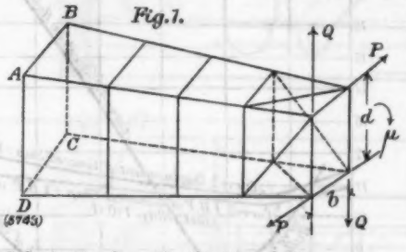
and

$$U_S = \frac{Q^2}{2 E} \Sigma X_1 \quad . \quad . \quad (5)$$

Then the total work done on the whole of the wires of the fuselage is U, where :

$$U = U_T + U_B + U_P + U_S$$

Fig. 1.



(5743)

Substituting from (2), (3), (4) and (5) :

$$U = \frac{P^2}{2 E} (\Sigma x + \Sigma x_1) + \frac{Q^2}{2 E} (\Sigma X + \Sigma X_1) \quad (6)$$

But from equation (1) :

$$P = \frac{\mu - Q b}{d}$$

Substitute this value in equation (6), which becomes :

$$U = \frac{(\mu - Q b)^2}{2 E d^2} (\Sigma x + \Sigma x_1) + \frac{Q^2}{2 E} (\Sigma X + \Sigma X_1)$$

The energy stored in the structure will be a minimum, *i.e.* :

$$\frac{d U}{d Q} = 0$$

∴ Differentiating U and equating to zero we obtain :

$$\frac{d U}{d Q} = \frac{Q}{E} (\Sigma X + \Sigma X_1) + \frac{b^2 Q - \mu b}{E d^2} (\Sigma x + \Sigma x_1) = 0$$

From which :

$$Q = \frac{\mu b (\Sigma x + \Sigma x_1)}{d^2 (\Sigma X + \Sigma X_1) + b^2 (\Sigma x + \Sigma x_1)} \quad (7)$$

Similarly :

$$P = \frac{\mu d (\Sigma X + \Sigma X_1)}{d^2 (\Sigma X + \Sigma X_1) + b^2 (\Sigma x + \Sigma x_1)} \quad (8)$$

In the case where the fuselage is symmetrical about a central longitudinal axis on each face :

$$k = k_1, a = a_1, l = l_1,$$
$$K = K_1, A = A_1, L = L_1$$
$$x = x_1 \text{ and } X = X_1$$

and equations (7) and (8) reduce to :

$$Q = \frac{\mu b (\Sigma x)}{d^2 \, 2 X + b^2 \Sigma x} \quad . \quad . \quad (9)$$

$$P = \frac{\mu d \Sigma X}{d^2 \Sigma X + b^2 \, 2 x} \quad . \quad . \quad (10)$$

Let θ be the angle turned through by one bay of the fuselage relative to the next and let U′ be the energy stored in the wires of this bay.

Then :

$$U' = \frac{P^2}{2 E} (x + x_1) + \frac{Q^2}{2 E} (X + X_1)$$

and

$$\tfrac{1}{2} \mu \theta = U'$$

or

$$\theta = \frac{2 U'}{\mu} \quad . \quad . \quad . \quad (11)$$

Let Θ be the total angle turned through by the end of the fuselage.

Then :

$$\Theta = \Sigma \theta = \frac{2}{\mu} \Sigma U'$$

But

$$\Sigma U' = U$$

$$\therefore \Theta = \frac{2 U}{\mu} \quad . \quad . \quad . \quad (12)$$

4. *Application of Method.*—The best method of applying the foregoing results is as follows : Draw stress diagrams for the four faces of the fuselage with unit loads applied in the appropriate directions, i.e., the directions indicated in the figure by the forces P, P, Q and Q. If the faces are symmetrical about a longitudinal axis two stress diagrams only will be needed, but if they are not, four must be drawn.

The loads in the wires scaled from these diagrams will equal numerically the values of K, K_1, k and k_1 required, and these should be tabulated. The values of L, L_1, l and l_1 are scaled direct from the frame diagram, and A, A_1, &c., are known. Hence the values of X, X_1, x and x_1 are known for every bay in the structure.

Summing these and substituting in equations (7) and (8) the values of P and Q are determined. On multiplying the various values of K, K_1, &c., by P and Q, the actual forces in the wires are obtained, and the problem is solved.

The best results are obtained by a system of tabulation as indicated below :—

1	2	3	4	5	6	11	16	21	22	23
Bay	K	K^2	L	A	$\frac{K^2 L}{A} = X$	$\frac{K_1 L_1}{A_1} = X_1$	X	X_1	U′	θ
	Scaled from stress diagram for unit load.		Scaled from frame diagram.	Calculated from dimensions of wire.						From equation (11)

In the suggested scheme the columns 7–10, 12–15 and 17–20 correspond to columns 2–5, and would, of course, be filled in. P and Q must be found first, and then column 22 is calculated from the known values of P and Q and the values of X, X_1, &c, found in columns 6, 11, &c. θ is finally found from equation (11).

The total angle of twist is found by summing column 23 at the conclusion of the calculations. It is not necessary to estimate the value of θ for all the bays, simply finding Θ for the whole fuselage by using equations (12) and (6). It is, however, an advantage to know the angle of twist for each panel, as any torsional weakness may be located by this means and corrected.

ECONOMIC SIZE OF CONCRETE SHIPS.

By E. O. WILLIAMS, B.Sc., A.M.I.C.E., A.I.N.A.

IT is often stated that the disadvantage of weight of concrete ships compared with steel ships diminishes with increased size of vessels, and it is possible that the construction of vessels of very large deadweight capacity might be favoured on that assumption. It was with a view to testing this statement that this study of the economic size of concrete ships was undertaken, and to suggest, if necessary, a limit to size.

It is obvious that for very small concrete vessels the thickness and sizes of concrete members are determined by practical considerations, and are greater than are required to withstand stresses. Generally speaking it is not practical to construct reinforced concrete walls less than 2 in. to 2½ in. thick, and no matter how small a vessel, the slabs and beams should not be less than this dimension. The same consideration affects the design of small steel ships, but not to the same extent, and therefore

small concrete ships of about 250 tons deadweight compare more unfavourably in weight with steel ships than if of a deadweight of about 1,000 tons.

Does the improvement in weight of concrete ships continue with still further increase in size? If not, at what deadweight capacity does the improvement cease. The saving of steel in a concrete vessel is greater for small than for larger vessels, for as steel ships increase in size the steel is used more economically. It can be shown from the theory of the design of concrete ships that the total tonnage of steel reinforcement varies as $\sqrt[3]{D^4}$ where D is the load displacement. In the determination of this formula it is assumed that the steel stresses remain constant for all sizes of ships, and up to the size of ships considered, this would hold good. It is thus clear that the tonnage of steel reinforcement increases at a greater rate than the load displacement.

(a) Comparison between Deadweight and Displacement of Concrete Ships.

—	Vessel 1c.	Vessel 2c.	Vessel 3c.	Vessel 4c.	Vessel 5c.
	tons.	tons.	tons.	tons.	tons.
1. Load displacement	1,630	2,500	4,150	10,000	15,000
2. Reinforcing steel..	85	150	290	900	1,550
3. Concrete	400	570	980	2,500	4,200
4. Fittings and outfit	90	135	200	350	450
5. Machinery ..	130	155	200	425	650
6. Lightweight ..	705	1,010	1,650	4,175	6,850
7. Deadweight (concrete ship) ..	925	1,490	2,500	5,825	8,150
8. Deadweight tons of steel ship of same displacement and indicated horse-power ..	1,020	1,600	2,780	7,060	10,720

(b) Steel Ships of Same Deadweight Capacities, as the above stated Concrete Ships.

—	Vessel 1s.	Vessel 2s.	Vessel 3s.	Vessel 4s.	Vessel 5s.
	tons.	tons.	tons.	tons.	tons.
1. Load displacement	1,495	2,350	3,780	8,375	11,490
2. Steel in hull ..	385	585	900	1,860	2,475
3. Fittings and outfit	80	135	190	325	380
4. Machinery ..	105	140	190	365	485
5. Lightweight ..	570	860	1,280	2,550	3,340
6. Deadweight ..	925	1,490	2,500	5,825	8,150

(c) Comparison between Steel Ships and Concrete Ships of Same Deadweight Capacity.

1. Deadweight capacities, tons ..	925	1,490	2,500	5,825	8,150
2. I.H.P. of concrete ship divided by I.H.P. steel ship ..	1·06	1·04	1·085	1·125	1·190
3. Tons of steel reinforcement divided by tons of steel in steel hull	0·22	0·26	0·32	0·48	0·62
4. Displacement of concrete ship divided by displacement of steel ship	1·09	1·07	1·09	1·19	1·30
5. Constant speed. I.H.P. concrete ship skin friction assumed equal ..	480	635	900	1,600	2,100
6. I.H.P. steel ship..	450	610	845	1,330	1,770
7. I.H.P. per ton deadweight of concrete ship	0·52	0·43	0·36	0·28	0·26
8. I.H.P. per ton deadweight of steel ship	0·49	0·41	0·34	0·23	0·21

In determining the necessary amount of concrete required to embed the steel bars, there must be a maximum limit to the ratio of steel to concrete. It is assumed in the following that the maximum limit is fixed only by the practical impossibility of pouring in the concrete satisfactorily if more than a certain maximum percentage of steel to concrete be employed in any part of a wall or slab and also that when that percentage is reached the concrete is of such a high quality as to transmit stresses satisfactorily on to the reinforcement. It is clear, therefore, that when the maximum practical percentage of steel reinforcement is reached the ratio of concrete to steel will become approximately constant for all larger ships, and then the weight of concrete will also increase as $\sqrt[3]{D^4}$ or at a greater rate than the displacement.

Table (*a*) has been calculated on the above assumptions except vessels 1c, 3c and 4c, which are actual designs, and in which the tonnage of steel reinforcement has been found to comply very nearly with $\sqrt[3]{D^4}$, which was determined independently, from first principles.

Table (*b*) gives the estimated particulars of steel ships of the same deadweight capacities.

Table (*c*) gives the comparative ratios between concrete and steel ships of the same deadweight capacity.

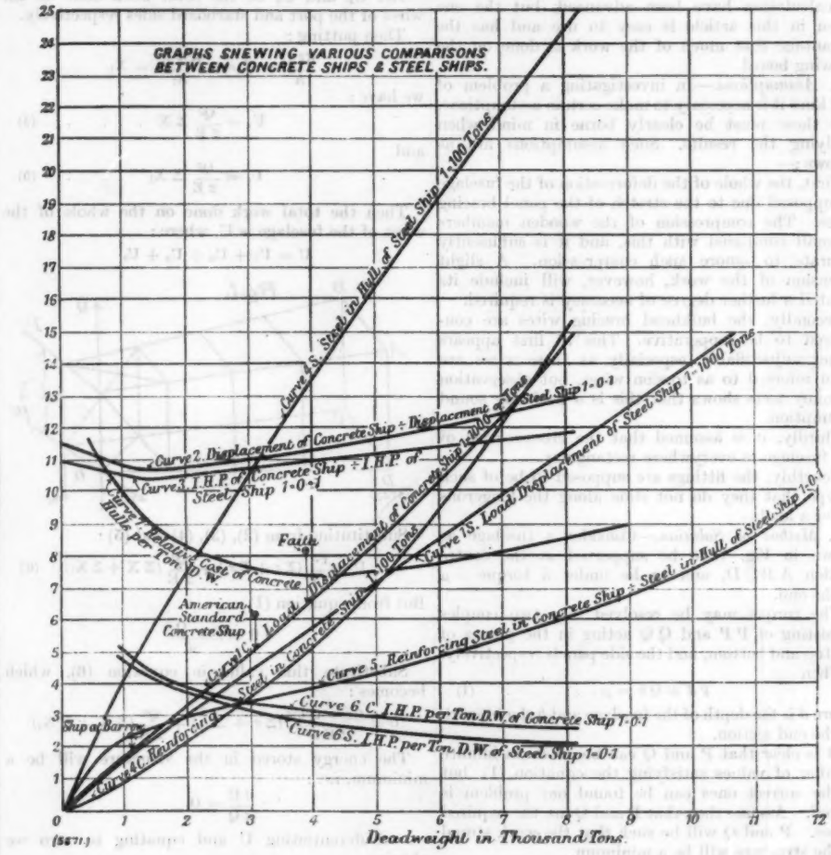
The following relationships have also been plotted as shown in the subjoined diagram.

Curve 1c. Variation of displacement with deadweight for concrete ship.

Curve 1s. Variation of displacement with deadweight for steel ship.

Curve 2. Ratio of load displacement of concrete ship to displacement of steel ship.

Curve 3. Ratio of indicated horse-power of concrete ship to indicated horse-power of steel ship of same deadweight capacity.


GRAPHS SHEWING VARIOUS COMPARISONS BETWEEN CONCRETE SHIPS & STEEL SHIPS.
Curve 4 S. Steel in Hull of Steel Ship 1-100 Tons
Curve 2. Displacement of Concrete Ship ÷ Displacement of Steel Ship 1-0-1
Curve 3. I.H.P. of Concrete Ship ÷ I.H.P. of Steel Ship 1-0-1
Curve 1S. Load Displacement of Steel Ship 1-1000 Tons
Curve 1C. Load Displacement of Concrete Ship 1-100 Tons
Curve 7. Relative Cost per Ton D.W. of Concrete Hulls
Faith
American Standard Concrete Ship
Steel in Concrete Ship ÷ Steel in Hull of Steel Ship 1-0-1
Curve 5. Reinforcing Steel in Concrete Ship ÷ Steel in Hull of Steel Ship 1-0-1
Curve 6 C. I.H.P. per Ton D.W. of Concrete Ship 1-0-1
Curve 6 S. I.H.P. per Ton D.W. of Steel Ship 1-0-1
Ship at Barrow
Curve 4 C. Reinforcing
(5671)
Deadweight in Thousand Tons.

Curve 4c. Variation of tons of steel reinforcement with deadweight for concrete ship.

Curve 4s. Variation of tons of steel in steel hull.

Curve 5. Variation in ratio

$$\frac{\text{weight of steel reinforcement}}{\text{weight of steel in steel hull}}$$

with deadweight.

Curve 6c. Variation of indicated horse-power per ton deadweight for concrete ship.

Curve 7. Variation of cost of reinforced concrete hull per ton deadweight.

The displacements of the Faith, America's standard concrete ship, and "Concrete Shipbuilding at Barrow,"* are indicated on the curve 1c. The displacements of "Shipbuilding at Barrow," "America's Standard Concrete Ship,"† and the Faith, are all about 20 per cent. more than would be anticipated from this curve, and this indicates that the concrete hull estimates which this curve represents make allowance for considerable improvements in design and materials, and are not pessimistic.

Examinations of curves 1c and 1s indicates that the displacement of concrete ships above 1,500 tons deadweight becomes increasingly greater than that of steel ships. Curve 2 also shows this very clearly, and it would appear that at a deadweight capacity of about 1,500 tons the displacement of concrete ships makes the nearest approach to steel, being in fact only 7 per cent. more.

The indicated horse-power ratio, Curve 3, naturally follows Curve 2, and at 1,500 tons deadweight the increase in indicated horse-power is only 4 per cent. Curve 6c shows that the indicated horse-power per ton deadweight does not decrease so rapidly with increase of deadweight as is the case with steel ships shown in Curve 6s. After 8,000 tons deadweight there appears to be no appreciable decrease in indicated horse-power per ton deadweight for concrete ships.

The saving in steel is an important economy of concrete ships, and Curve 5 indicates that the ratio $\frac{\text{steel in reinforcement}}{\text{steel in steel hull}}$ increases rapidly with dead weight. The saving in steel is about 77 per cent. for 1,000 tons deadweight, 50 per cent. for 6,000 tons deadweight, and probably becomes nil at about 12,000 tons deadweight. This alone indicates an economic limit to size of concrete ships.

The cost of concrete hulls is governed largely by the superficial area of hull. The cost of moulds, and steel placing varies directly as the area of the hull. It is possible that the total cost of labour on steel in a 2,500-tonner concrete ship would not be much more than for a 1,000-tonner. The tonnage of reinforcement would be about three times as much, but if individual bars are three times the area of similarly positioned bars in the smaller boats, such as $\frac{3}{8}$-in. bars instead of $\frac{1}{8}$-in. bars, the total cost of handling would not be much greater. In larger boats there is more room in which to place the moulds and generally the workmen are not working under such difficult and congested conditions. The cost of fairing fore and aft ends is not much more for a large ship than for a small ship, which is again an advantage in cost in favour of the larger ship.

* See Engineering, vol. cv, page 335.
† See Engineering, vol. cvi, page 326.

The area of hull varies as $\sqrt[3]{D^2}$, and thus it would appear that the cost of concrete ships per ton deadweight decreases with increase of size of hull, with the exception of the cost of concrete and steel, which increases with the weight of material. Thus the cost of concrete ships can be divided into two parts, one varying with $\sqrt[3]{D^2}$, the other part directly with the weight of hull.

Curve 7 illustrates the variation in cost of concrete hull per ton deadweight, the figure for a 1,000-tonner being unity, the curve combining the effect on cost of weight of hull and area of hull surface. From Curve 7 the advantage in capital outlay of building 4,000-tonners is apparent, the cost per ton deadweight being 75 per cent. of that of a 1,000-tonner, but after 4,000 tons deadweight, the cost per ton deadweight increases owing to the cost of materials becoming the predominating item

The facts to be derived from these curves are :—

1. After 1,500 tons deadweight the displacement of concrete hulls increases more rapidly than the increase of deadweight.

2. Minimum indicated horse-power per ton deadweight of concrete ship occurs at 8,000 tons deadweight.

3. Minimum cost of concrete hull occurs at 4,000 tons deadweight.

4. From (3) and (4) it would appear that the economic limit to concrete ships is between 5,000 tons and 8,000 tons deadweight.

5. At 1,500 tons deadweight the concrete ship is most favourably compared with a steel ship for displacement and indicated horse-power and at this deadweight the cost per ton deadweight is 90 per cent. that of a 1,000-tonner.

6. The saving of steel at 1,500 tons deadweight is 74 per cent. The saving of steel at 8,000 tons deadweight is 38 per cent.

7. Vessels above 8,000 tons deadweight are not economic in concrete because :—

(*a*) Saving of steel becomes negligible, and at 12,000 tons deadweight there is no saving in steel.

(*b*) Cost of hull per ton deadweight rapidly increases.

(*c*) Displacement rapidly increases and consequently indicated horse-power and net tonnage.

8. To conclude, concrete ships are most economical between deadweights of 1,500 tons and 4,000 tons, and the best size concrete ship, considering initial cost of hull, indicated horse-power and saving in steel, is in the neighbourhood of 3,500 tons deadweight. No concrete ship under 4,000 tons deadweight should require more than 10 per cent. extra propelling power compared with a steel ship of the same capacity. In vessels under 1,000 tons deadweight the saving of steel is very considerable, being over 90 per cent. for 100 tons deadweight, and this alone will in many cases lead to the adoption of concrete. If, however, the object is to increase tonnage at minimum cost and irrespective of size of ship, it would be advisable to build vessels of about 3,500 tons deadweight.

The above conclusions are based on a steel tensile stress of 7 tons per square inch. If higher tensile steel were used and the ratio of concrete to steel remained constant it would enable the weight of concrete to be reduced provided the concrete could stand the still higher demands made upon it. If this were possible the weight of hull would be reduced and the economic limit of size increased, but not very considerably.

Another possible means of reducing the displacement of concrete ships would be by the use of a concrete of lower specific gravity, and this is the most likely and immediate improvement.

TEMPLETS, JIGS AND FIXTURES.
No. XX.

By JOSEPH HORNER.

THE machine vices and vice-like fixtures that hold articles singly or in series avoid direct bolting to machine tables. Instead of being made for one particular article of manufacture they are stocked to be employed for numerous types and sizes of work, with the object of saving the excessive amount of time otherwise occupied in setting and fixing pieces without their aid, with the doubtful assistance of loose and miscellaneous helps picked up at random. They form large, important, and constantly-growing groups. They are often home-made articles, but several firms undertake their manufacture and supply improved and better-fitted appliances than those made generally in the shops.

Again, a large volume of small work is done in vice fixtures which are appliances of a simple character that are inserted and gripped in the vice jaws in the forms of clams or false jaws of a special and temporary character. The vice is then a standard body—a base, the false jaws are its locating elements. Very high elaboration here is not to be looked for, but for holding many articles of simple outlines the vice, with its special attachments, occupies an economical field, and it is utilised increasingly. A very large proportion of ordinary tooling is done on work held thus in drilling, planing, shaping and milling machines. Pieces are gripped singly or in series. Parallel and tapered pieces are thus held, cylindrical forms are laid horizontally or disposed vertically, faces are tooled in horizontal, vertical, or angular relations, short pieces, or those of great length. The important matters that have to be observed are rapidity of location, a suitable and sufficient grip, and a high degree of precision. Some of these concern the kind of vice used, others the character of false jaws fitted. Improved forms of vices have been favourable to their employment for this service. The older designs are too inelastic, too limited in utilities, too slow for a good many of the requirements of fixture work.

Rapidity of movement of vice jaws is as desirable as it is in the regular fixtures. Moments are precious since, as we have seen, the time of setting up must needs occupy but a small, and generally a lessening proportion to that occupied in the actual tooling. Hence the reason of the numerous devices which have for their objects the avoidance of tedious removals and replacements of elements, such parts as bolts, screws, washers, clamp plates, lever handles, slotted washers, hinged fittings, rapid cam movements, quick insertion and removal of bushes, and so on. Naturally, therefore, those machine vices which include provisions for quick action are those which are regarded with high favour for fixture work. They do not wholly displace the others, since there is room for both. The ordinary machine vice which has no quick action and has its jaws set rigidly square, and can only hold parallel pieces, is suitable enough for a very large run of work. It is used for small articles without number that have parallel faces. It is attached to the tables of small planing machines, but more frequently on those of the shaper, the milling, and the drilling machines. By its use the labour and delay involved in bolting pieces directly on the machine table is avoided. It is frequently to be preferred to the angle plate or the vee blocks. As much vice work is repetitive, the slow adjustment of the loose jaw by a screw working in a solid nut is of no consequence, since the width of opening is not varied materially when dealing with a run of standard work. Many simple fixtures are made for these vices—false jaws cut and shaped to receive and locate precisely pieces that have to be tooled in large numbers, in which precise relations of parts have to be preserved, articles that cannot be held between parallel jaws with plane faces, pieces that must be tooled all alike without entailing the labour of making tedious tentative adjustments, and for which a suitable and sufficient form of grip must be provided to resist the pressure of cutting.

One of the most useful provisions embodied in some machine vices is that of a downward pressure exercised by the jaws when they grip the work. In the ordinary rigid-faced jaws there is no certainty that the work held in them will bed perfectly on the vice base, or on an inserted packing. The turning of the screw may cause the work to lift

Fig. 586.

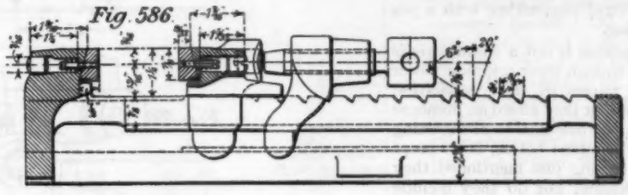


Fig. 587.

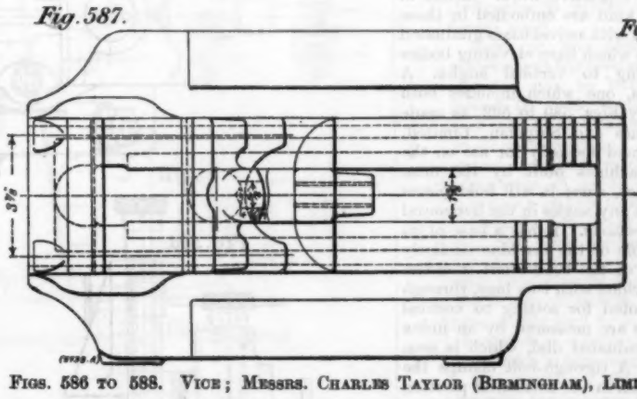


Fig. 588.

FIGS. 586 TO 588. VICE; MESSRS. CHARLES TAYLOR (BIRMINGHAM), LIMITED, BIRMINGHAM.

slightly, hence the reason why light tapping down of the work is usually necessary to ensure good bedding. The provision for bedding-down the piece gripped as embodied in the Taylor vice is shown by Figs. 586 to 588. This is by Charles Taylor (Birmingham), Limited, Birmingham. The jaw plates A, A, are not screwed so rigidly to their backings that they are not free to move, and they are not attached to vertical faces. The meeting faces are undercut, Fig. 587, and the holes through which the attachment screws pass are deeper than the screws. The result is that when the grip comes on the work the jaw plates slide downwards very slightly, taking the work with them, until it beds closely. Coiled springs encircling the screws, and a leaf spring in a recess underneath each plate, throw the jaws up again on the release of the grip.

For the gripping of the loose jaw a distinct push or abutment jaw B is provided in the rear of the actual work-holding jaw. The abutment jaw has teeth on its base, which, being dropped into one of the series of serrations cut across the top face of the vice body, anchor it. The serrations form strong abutments, which receive the reaction thrust of the push jaw. The pressure of the abutment screw is taken on a hardened steel plug let into the back of the gripping jaw. To release the push jaw, the screw being slackened, the jaw is tilted forward, so lifting it out of the serrations, when it and the working jaw can be moved where needed.

Quick-action vices of this class differ from the instantaneous grip vices of the bench, in the absence of the long, continuous screw, which, when thrown

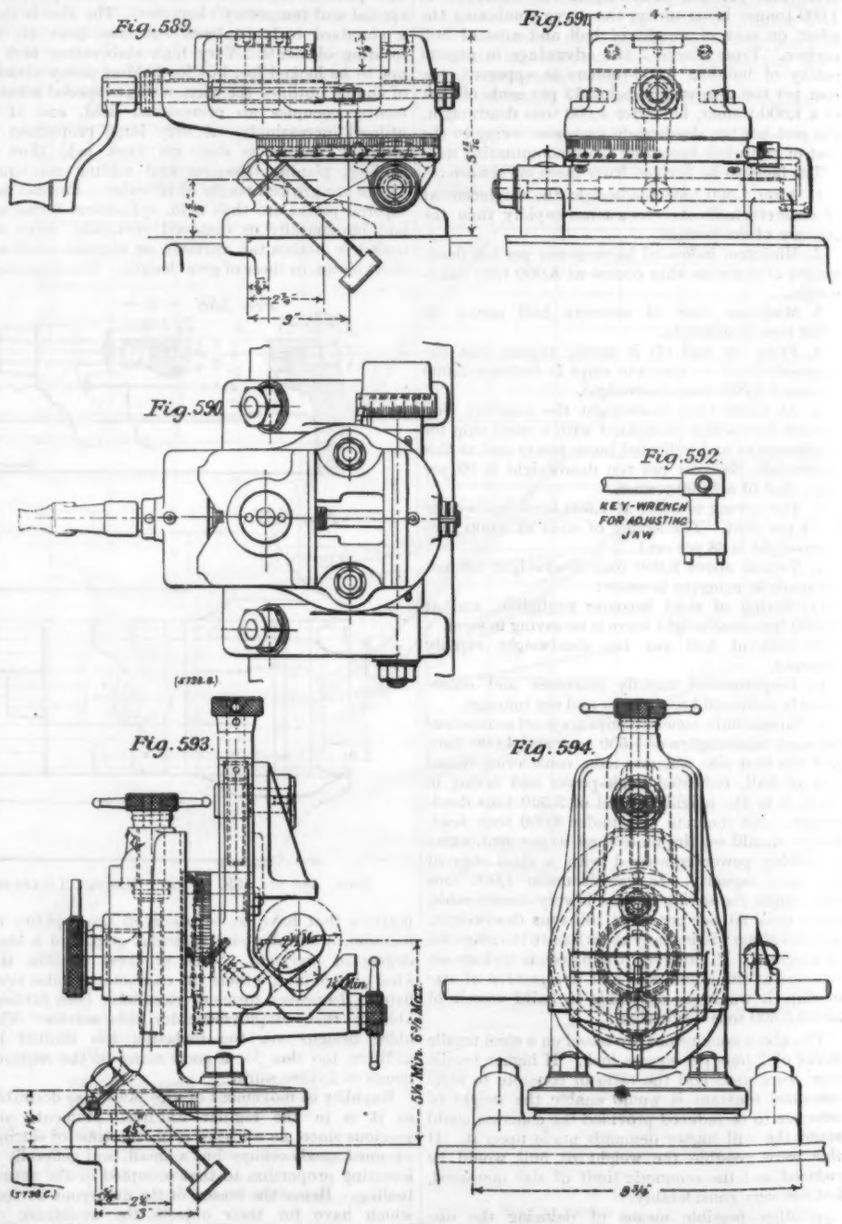
out of mesh with its nut by means of an eccentric motion, permits the rapid movement of the loose jaw to a new position, after which the nut is thrown into mesh again. The abandonment of the horizontal screw leaves a clear opening through the base of the vice, into which work may be passed down, or drills or reamers clear. This is a distinct advantage, in addition to that afforded by the rapid movement of the jaw. It will, in some cases, avoid the employment of deep, false jaws to hold work having projecting bosses or stems, or that in which drills and chips must clear through the bottom face.

There is another and an equal benefit embodied in these vice designs. The jaws can swivel to take tapered pieces as well as those which are parallel, which very materially enlarges their range of usefulness. Tapered objects comprise a large proportion of those which have to be tooled, such as levers, gibs, and cottars, keys and wedge take-ups. Packings are commonly used for these in vices with parallel jaws, but time is saved when a jaw will swivel and accommodate itself to any taper. Swivel is effected in a good many ways. In Fig. 587 a cylindrical stem on the loose jaw fits within the slot in the base. Sometimes loose jaws are pivoted against a rigid jaw, either with a pin or with a concave seating.

A high degree of precision is not a characteristic of these vices, efficient though their gripping power is, and adequate the ranges of their capacities. Within their sphere of action they afford an immense economical advance on the alternative of fastening articles directly to the machine tables, but except for the plain kinds of tooling just mentioned they are not fixtures of precision, nor do they include means of location for repetitive work. Means of precise setting of one kind are embodied in those vice which are provided with swivel bases graduated into degrees, and those which have elevating bodies with means of setting to vertical angles. A universal vice, that is, one which includes both provisions, is shown by Figs. 589 to 592, as made by Messrs. A. A. Jones and Shipman, Limited, of Leicester, and designed specially for use on the Universal grinding machines built by the firm. It is a valuable adjunct, since it will hold pieces of almost any shapes at any angles in the horizontal and in the vertical directions. It has a base of its own, bolted to the table of the machine similarly to the standard base 'or the heads, but it differs from this in being provided with two lugs, through which the vice is pivoted for setting to vertical angles. These settings are measured by an index pointer on the side graduated dial, which is seen in Figs. 589 to 591. A through-bolt clamps the circular vice base. When in the horizontal position the vice base rests on an abutment at the bottom. The body swivels round a horizontal plane on the base to any angle, and is clamped with two tee-head bolts. Graduations are also provided for these settings. One jaw of the vice, that on the right, is solid with the body. The other is adjustable with the cranked lever and screw. The screw nut is prolonged into a pivot above, on which the jaw swivels, so that tapered articles, or those having uneven contours can be gripped. The jaw can also be turned right round to bring its hinder vee'd face into opposition with the fixed jaw to hold circular pieces. To adjust the jaw the key wrench. Fig. 592, is employed. The jaws are steel-faced.

The provision by which jaws can be turned right round to present two faces to the solid fixed jaw enlarges greatly the utility of a vice. Frequently it is extended by the use of two independent jaws bolted directly to a machine table instead of to a vice base, the advantage gained being that of securing articles which are too long to be gripped between the jaws of any single vice, the only limit then being that of the length which a machine table will accommodate. These are frequently combined with special jaws, solid, or false, those of vee'd shapes being prominent, and those of numerous other forms to grip articles of particular outlines.

The influence of jig and fixture practice extends into fields that lie beyond that occupied by the appliances which are extraneous to, and independent of, the machine tool. Beyond the fact that these are bolted to, or laid on a machine table, they bear no special relation to the tool on which they are used. But outside this group, very many fixtures and jigs are designed with special regard and suitability to the machine on which they are to be regularly employed, and on no others; to be used on some particular product that may be required for an indefinite period. Examples of this kind have become familiar in the vast work of munitions, but they are also apparent in other fields outside that. In some instances, these attachments are fitted to render the machines of a universal or a



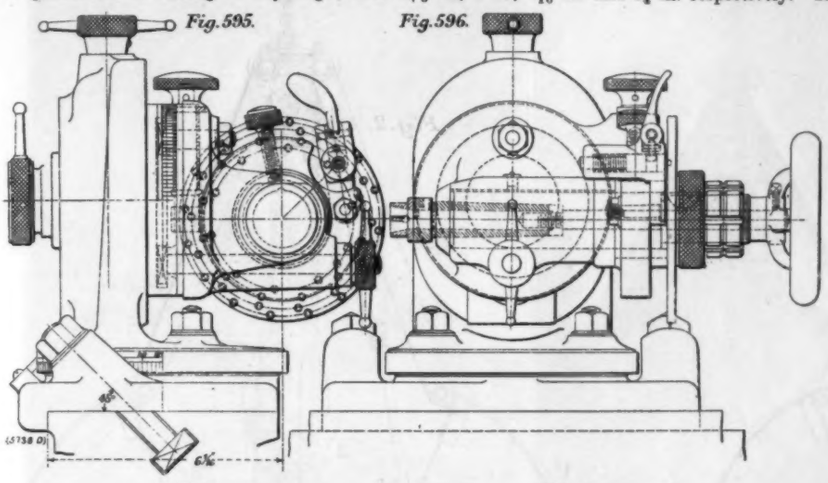
Figs. 589 to 594. Work-Holding Appliances; Messrs. A. A. Jones and Shipman, Ltd., Leicester.

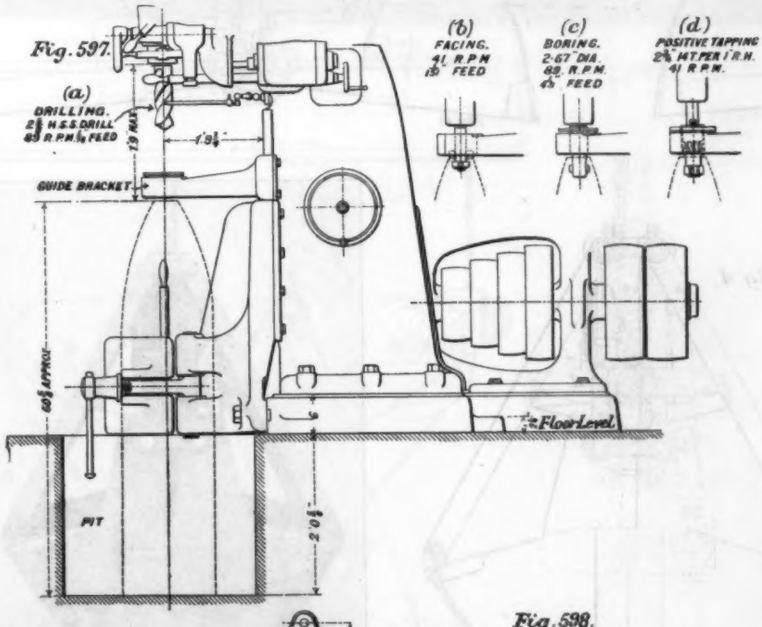
combination character, but in others they are designed to perform one operation or class of operations. These occur in all the great groups of machine tools, lathes, drilling machines, grinders planers, milling machines, no single group having a monopoly of them. The machine vice just illustrated is an example of this kind. Succeeding illustrations are those of attachments, which also supplement and enhance the utilities of a single machine tool—the 24-in. by 12-in. Universal grinding machine, by Messrs. A. A. Jones and Shipman, Limited.

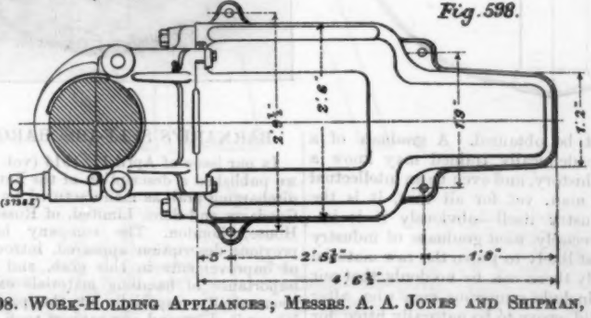
A universal vee-clamping fixture, Figs. 593 and 594, is used to hold all kinds of cutters and arbours to be ground. The base is similar to that for the universal work head. The upright portion receives the circular face, which is moved vertically with the knurled head above, and its screw, from a minimum of 5¼ in. to a maximum of 6⅝ in., height of centres from the table of the machine. It is clamped when set for height by the knurled nut at the rear. The circular plate, the edge of which is graduated, receives the work-holding portion to be turned to any angle, and clamped with the tee-head bolts in an annular slot. The lower vee'd jaw is solid with its body, the upper jaw pivots on a pin going through its upper portion, so that it will accommodate itself to any shape, tapered or irregular. It is adjustable vertically by the knurled head and screw to receive work ranging from 1¼ in. to 2¼ in. across. Articles are gripped between three points, two in the vee and one in the loose jaw. An end stop sliding on a bar is provided to locate the work, whether cutter shank or arbour, in relation to the grinding wheel. The double series of graduations—those around the base, and those around the edge of the vertical circular face—permit of setting work to any compound angles desired.

Figs. 595 and 596 illustrate a gear-cutter grinding

attachment. Like the other fixtures, it is secured to the table with two bolts set at an angle of 45 deg. to suit the tee-slot in the table, these bolts pulling it against the square guiding edge. The base is standard, in order to receive the universal work-head of the machine and other substituted fixtures. It is graduated for setting to any angle, and is clamped with two bolts. The upright portion of the body in one with the base has guiding ways, over which the circular face is adjusted vertically, to the extent of 1½ in., by turning the knurled head screw. The maximum height of centre is 5⅞ in. It is locked with the knurled head at the rear. The edge of the circular face is graduated to permit of setting the work-holder to any angle, when it is clamped with the two tee-head bolts moving in an annular groove. The boss of the holder receives a draw-in chuck, pulled in with a bolt and hand wheel. The spindle is hollow, and is bored to a No. 3 Morse taper to accommodate taper shank cutters, arbours, &c.; and is also used for operating draw-in collets to expand into the bores of plain cutters. It receives four collets to take bores of ⅞ in., 1 in., 1 1/16 in. and 1¼ in. respectively. The pitching is effected through a division plate provided with four circles of holes, the peg for which is moved in or out with the spring plunger and latch. The plate is turned with a knurled head, which revolves a worm and its gear. The four circles of holes number 16, 14, 12 and 10 respectively. Plates with different numbers of divisions can be supplied. The peg is brought to either circle by moving it with its holder round the bolt on which the holder pivots. A cup or saucer-shaped wheel is brought over the centre line of the attachment. The feed is operated radially through a fine-pitch worm and worm wheel, ensuring the cutting edges being maintained in correct relation to the centre.







FIGS. 595 TO 598. WORK-HOLDING APPLIANCES; MESSRS. A. A. JONES AND SHIPMAN, LTD., LEICESTER.

An attachment to a drilling machine for tooling the noses of high-explosive shells subsequent to bottling, is shown by Figs. 597 and 598. It is carried beneath the steady guide bracket, taking the place of the machine table. The body of the holder is gibbed to the vertical face of the machine frame to receive the shell case, the lower portion of which goes down into a pit. The shell is clamped quickly with a hinged cap, and secured rapidly with a swing bolt. The successive operations are drilling, facing, boring and tapping, particulars of which are stated on the illustration.

THE EMPLOYMENT MANAGER.

AMONG other results of the war period, the re-assessment of human valuation in industrial pursuits is outstanding. Those who attempt to follow the complexities of this transvaluation are struck by the very great difference in the perspective afforded by the new point of view. Various as have been the causes of past conditions; anxious as is the present period; the economic use of available human material is in the best interest of all concerned. Due to the withdrawal of the usual excess and normal supply of workers, methods have been set in operation whereby in place of diminished output on a falling scale of man-power, production has actually increased. The newer methods are one legacy from a time of stress and crisis impossible to minimise, and since the result has been to increase total wealth productive power, civilisation is hardly likely to suffer relapse into former ways.

Moreover, and this is most important, such achievement has been effected by economy in human material, not by human sacrifice; it has been gained by patient study and investigation, has been won by real endeavour, and as yet is only at an elementary stage. It is little understood that a second industrial revolution comparable with the application of power to toil, which was the first, is actually at this moment in process of being.

Hitherto, because of apparent superfluity, civilisation has been prodigal in its wastage of man-power; now, man-power must be conserved and used economically like any other gift of Nature. While demobilisation, sudden and general, might conceivably lead to a crisis due to difficulty in re-absorption; wisdom as to priority, quantity and proportion is becoming evident.

The matter of the human force in relation to industry has received more first-hand consideration in the United States of America than anywhere else, several things served to give an impetus there; higher wages and standards of life had a bearing as well as the larger scale upon which industry was framed.

It is many years ago now that the rather immature science of psychology applied some of its conclusions to practical problems with an interesting measure of success. The problems connected with employment, correct selection of men and the minimising of fatigue, have received unwonted attention here latterly; the question of war production without stint having created problems on a large scale.

A very interesting and able article on "The Employment Manager," from the pen of an American authority—Mr. Meyer Bloomfield—appeared on January 16, last, in the London *Daily News*. He there reviews a new profession which demands trained brains, a special viewpoint, and a broad outlook. Employment; that is the hiring of staff and labour force, the fitting of square men in square holes, should be the function of specially trained men, is his argument. An extract is illuminating:—

"Employment is, at bottom, a venture in co-operation. Irresponsible hiring and discharge in the hands of many little executives is a costly and wasteful thing, viewed from the standpoint of good management; and from the side of the men, it goes contrary to their instinct as to how human beings should be dealt with in the human relation. "The traditional way in building up a working force or filling job vacancies is to make a vague and

BARNARD'S SELF-DISCHARGING GRAB.

CONSTRUCTED BY MESSRS. WM. GOODACRE AND CO., LIMITED, ENGINEERS, LONDON.

Fig. 1.

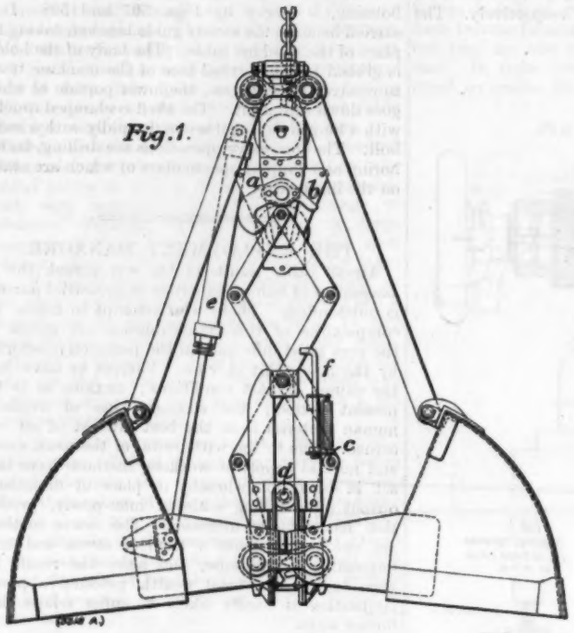


Fig. 2.

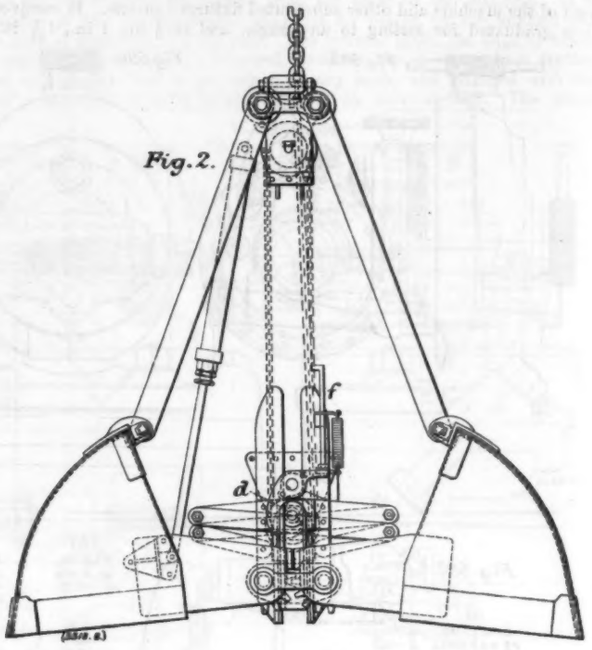


Fig. 3.

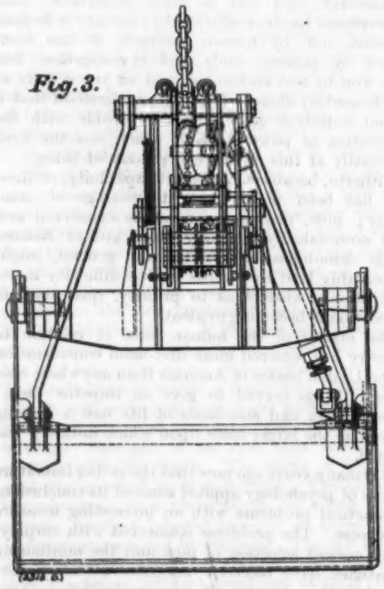
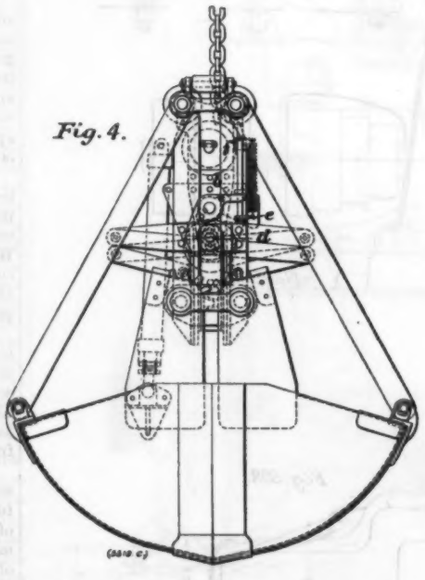
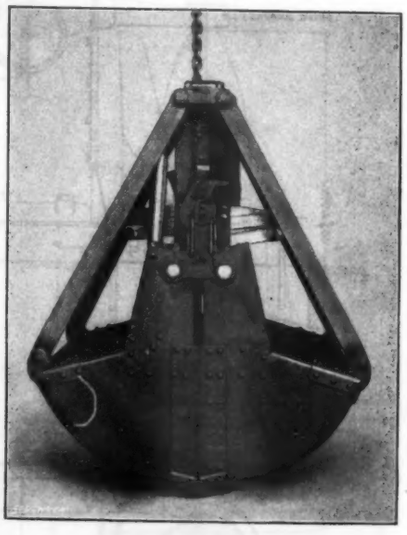


Fig. 4.





wholesale demand for labour and then pick at random from the crowds at the gate. All sorts of little bosses are kings in their own domain, with unchecked authority over that most vital interest in a workers life—his livelihood. Taken at its lowest, this is bad business demonstrated by the wasteful coming and going of men in and out of the jobs."

The article is unusual, although the American conditions and problems differ rather widely from those here, where attention has been devoted to the question on rather different lines. Another passage worth reproduction runs:—"There can be no doubt that an enlightened system of recruiting labour, careful and fair selection of workers, systematic provision for their advancement, encouragement in their progress, and protection against abuse of authority, is a distinct contribution to sound relations."

The writer advocates another specialist profession, set apart for employment management; but he fails to point out where recruits for the particular activity can best be obtained. A graduate of a college course academically trained may know a deal of industrial history, and even be an intellectual and widely-read man, yet for all that, it is the graduate of industry itself—obviously it is impossible to say precisely, *what* graduate of industry—who is the most likely to prove the raw material desired. Certainly there can be no doubt that our industrial ranks include numerous men who, after due training, would prove to be naturally fitted for such a post as that suggested.

Actually, employment management is less a new profession than a new idea, without doubt of very great value; but one which need not involve the special creation of a brand new expert to fill a totally new function. However, the article we have quoted is worth digestion by every executive mind responsible for production, although specific attention with corresponding results is being more generally given to such problems in Great Britain.

BARNARD'S SELF-DISCHARGING GRAB.

In our issue of April 17, 1914 (vol. xcvii page 524), we published a description of the Barnard patent self-discharging grab as manufactured by Messrs. William Goodacre and Sons, Limited, of Russell-road, Custom House, London. The company have, since our previous description appeared, introduced a number of improvements in this grab, and in view of the importance of handling materials expeditiously and economically, especially at the present time when labour is short and any savings such as ship hours at the quay side must be taken advantage of, we think it well to describe these modifications.

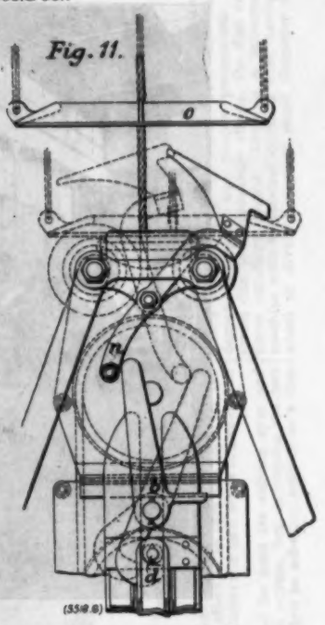
The latest form of Barnard grab is shown in Figs. 1 to 7, on the present and opposite pages, and on comparing these views with the previous illustrations it will be seen that the operating mechanism for opening and closing the grab has been modified, resulting in a much more simple design combined with a reduction in the number of working parts. The grab, which works on the block and tackle principle, and is of the self-acting type, is operated in the following

BARNARD'S SELF-DISCHARGING GRAB.

CONSTRUCTED BY MESSRS. WM. GOODACRE AND CO., LIMITED, ENGINEERS, LONDON.

FIG. 6.

FIG. 7.



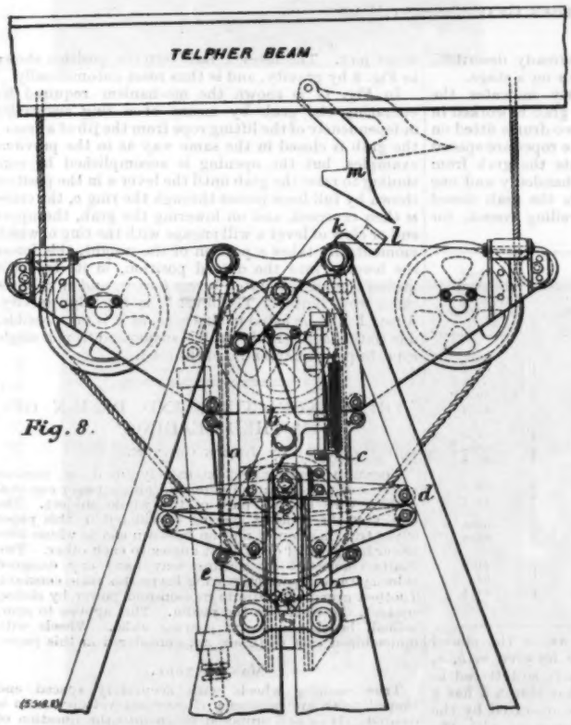


Fig. 8.

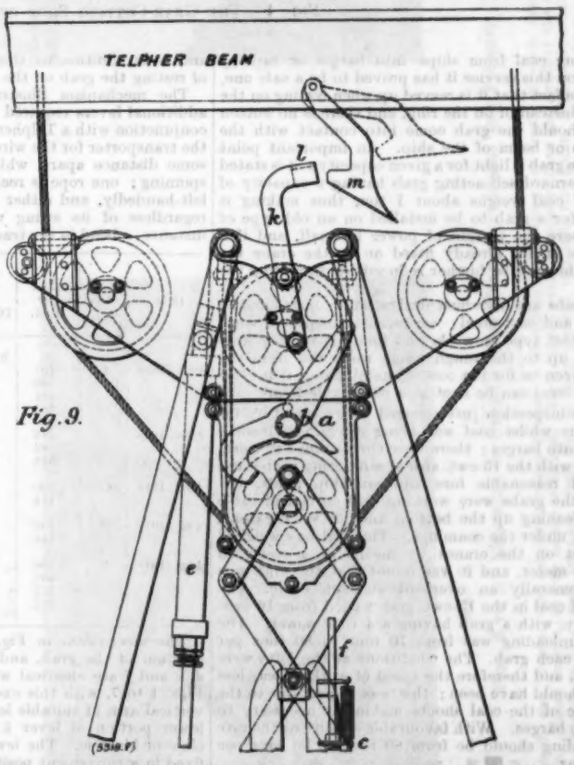


Fig. 9.

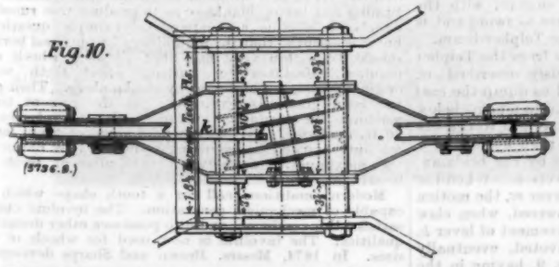


Fig. 10.

manner: The grab in the open position, Fig. 1, is lowered by the crane on to the material to be unloaded, the lowering of the sheave block *a* is continued after the grab rests on the material until the spigot on one of the clutches *b* comes into contact with the spring-operated plate *c*. The weight of the sheave block overcomes the tension of the spring which draws the clutches *b* under the pins *d*. When the block has dropped into its lowest position, Fig. 2, it is ready to be closed; to effect this the crane is reversed and the lifting rope hauled in; this closes the grab, but just prior to the grab being completely closed the spring rod *f*, shown in Figs. 1 and 2, comes into contact with one of the top bars and is pressed down free of the spigot on the clutch *b*. To re-open the grab it is necessary to rest it on a stage, or on the material being handled, slacken the hoisting rope a few inches, the clutches will then be swung out of position and clear of the pins *d* by the counterweights shown at *h* on Figs. 6 and 7; on reversing the crane and lifting the grab it will re-open; the speed of opening being regulated by means of the oil dash pot *e*, Fig. 1.

The grab is suitable for use on a crane fitted with either a rope or chain, the former is fast becoming the standard on account of (*a*) the weight when compared with a chain for a given load, and (*b*) safety due to the warning of failure given by a broken wire in the rope; but should the grab be required for working on a wharf where the same types of crane are not in use, the company are prepared to supply grabs which may be alternatively fitted up for use with either rope or chain.

The self-acting grab is being extensively used for

THE MANUFACTURE OF TOOTHED GEARING.

Fig. 1 The Gear-Cutting Shop of the Citroen Gear Company, Paris.

discharging coal from ships into barges or railway trucks; on this service it has proved to be a safe one, due to the fact that it is reeved up when resting on the material instead of on the ring, and there is no button to slip should the grab come into contact with the combings or beam of the ship. An important point is that the grab is light for a given capacity; it is stated that a Barnard self-acting grab having a capacity of 1 ton of coal weighs about 1 ton, thus making it possible for a grab to be installed on an old type of crane where the margin of power is small, and if a wire rope is not already fitted on to the crane the deadweight may be further reduced by discarding the chain.

The grabs are of robust design, and constructed of wrought and cast steel; we recently inspected some of the latest type at work, and found that they were standing up to the rough usage well, and from the figures given us for the cost of maintenance it is clear that this item can be kept at a reasonable figure.

At the inspection just referred to we stood-by for some time whilst coal was being discharged from a steamer into barges; there were three cranes at work, all fitted with the 15-cwt. size of self-acting grab; the ship had reasonable fore and mid-ship holds, but even so the grabs were working well on considerable slopes, cleaning up the bottom and, to some extent, trimming under the coamings. The coal was weighed in transit on the cranes by means of a steelyard weighing meter, and it was found that the grab was taking generally an overload at each cycle. The weight of coal in the 15-cwt. grab varied from 16 cwt. to 18 cwt. with a grab having a 4 to 1 power. The rate of unloading was from 70 tons to 80 tons per hour for each grab. The conditions at the jetty were not good, and therefore the speed of working was less than it should have been; this was in part due to the bad state of the coal shoots making it necessary to swing the barges. With favourable conditions the rate of unloading should be from 80 tons to 90 tons per crane-hour.

The annexed interesting figures of unloading coal from ships to barges at a coal jetty in the London area have been given to us by the company; they represent ordinary working from ships whose holds vary considerably, and include the time required for trimming and swinging the barges.

Four cranes, with fixed jibs, were available, fitted with Barnard's 15-cwt. self-acting grabs.

Due to the fact that the grab on this system of working rests when discharging on the bed of material or on a stage built upon the shoot, the breakage of coal is considerably reduced and, further, the loss and nuisance due to the dust is appreciably lessened.

The illustrations, Figs. 8, 9 and 10, show the mechanism fitted in order that the coal may be dumped automatically from a predetermined position of the grab and is in addition to the method already described, of resting the grab on the material or on a stage.

The mechanism illustrated clearly indicates the additional levers required when the grab is worked in conjunction with a Telpher having two drums fitted on the transporter for the wire ropes, the ropes are spaced some distance apart, which prevents the grab from spinning; one rope is reeved right-handedly and one left-handedly, and either rope holds the grab closed regardless of its swing when travelling round, for instance, a bend in the track.

Date.	Ship.	Tons per Hold.	Time to Discharge.	Cranes at Work.	Coal Discharged from Hold per Hour.
			hrs. min.		tons.
Mar., 1918	A	491	7 40	4	64·2
		558	8 40		64·4
		481	8 05		59·5
		383	8 05		47·4
June, 1918	B	548	8 05	3	67·8
		582	8 30		68·4
		553	8 10		67·8
Aug., 1918	C	390	5 35	2	69·8
		414	5 39		73·2
Aug., 1918	D	400	6 50	2	58·5
		454	6 30		69·8
Aug., 1918	E	280	5 30	4	51·0
		402	6 15		64·3
		372	6 50		54·4
		252	6 00		42·0

The mechanism in Fig. 8 is shown in the closed position of the grab, and the parts lettered *a*, *b*, *c*, *d*, *e* and *f* are identical with the parts so lettered in Figs. 1 to 7, with this exception, that clutch *b* has a vertical arm of suitable length to be operated by the lower portion of lever *k* when it engages with the claw of lever *m*. The lever *m* is free to swing and is fixed in a convenient position to the Telpher beam.

The grab, suspended by the ropes from the Telpher and having been closed as previously described, is, prior to being automatically opened to dump the coal or other material from a height, lifted to a point below lever *m*; the transporter is then traversed to the site and the material released from the grab by raising it until lever *m* is pushed to one side by the bridging-piece *l*, fixed to and connecting levers *k*. When the bridging-piece is above the claw of lever *m*, the motion is reversed, and the grab slowly lowered, when claw of lever *m* arrests the downward movement of lever *k*, which, being at an angle and pivoted, eventually takes up the position shown in Fig. 9, having in the short interval forced the clutches *b* over, and thus released pins *d*. The weight of the grab and its load is not entirely taken off the ropes, and therefore there is no jerk. The lever *k* falls into the position shown in Fig. 8 by gravity, and is thus reset automatically.

In Fig. 11 is shown the mechanism required for operating the grab by means of a ring suspended independently of the lifting rope from the jib of a crane; the grab is closed in the same way as in the previous examples, but the opening is accomplished by continuing to raise the grab until the lever *n* in the position shown by full lines passes through the ring *o*, the crane is then reversed, and on lowering the grab, the upper end or claw of lever *n* will engage with the ring *o*, which momentarily takes a portion of the weight, this forces the lever *n* into the dotted position, in its travel it pushes the arm of clutch levers *b* over, and so releases them from pins *d*. The lever *n* is reset by gravity. A ring has to be fitted in this case, as it is not possible, due to the fact that the grab is suspended from a single rope, to prevent spinning of the load.

THE MANUFACTURE AND DESIGN OF TOOTHED GEARING.*

By Joseph Chilton.

Toothed gearing is extensively used in modern systems of power transmission. A single paper can deal with a very limited part of the whole subject. The object of the toothed gearing considered in this paper is the transmission of motion between shafts whose axes are either parallel or at right angles to each other. Two shafts connected by gearing may have any designed velocity ratio; perfect gearing keeps this ratio constant. Toothed gearing transmits motion and power by sliding contact, the teeth are the media. This applies to spur, helical, bevel and worm gearing alike. Wheels with unmachined cast teeth are not considered in this paper.

Manufacture.

True running wheels with accurately spaced and shaped teeth are necessary if constant velocity ratio is desired. It is not proposed to go into the question of turning and boring blanks so as to produce true running wheels, as this is a comparatively simple question; but it is essential that the preliminary turning and boring should be within very fine limits if good wheels are required. Machines for cutting wheel teeth were originally designed and used by clockmakers. Their use has been gradually extended; at the present time machines are made for cutting teeth in steel wheels 30 ft. diameter. The accuracy of some of these large machines is such that in cutting a wheel of 10 ft. diameter the maximum error between two adjacent teeth is 0·0015 in.

Modern conditions call for a tooth shape which is capable of mechanical generation. The involute curve satisfies this condition, and also possesses other desirable qualities. The involute is now used for wheels of all sizes. In 1874, Messrs. Brown and Sharpe developed

* Paper read at the North-East Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne, February 11, 1919.

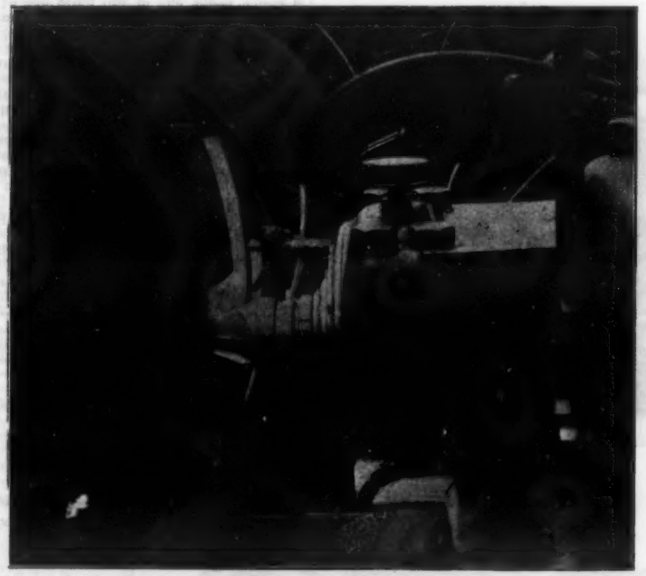


FIG. 2.

FIG. 3.

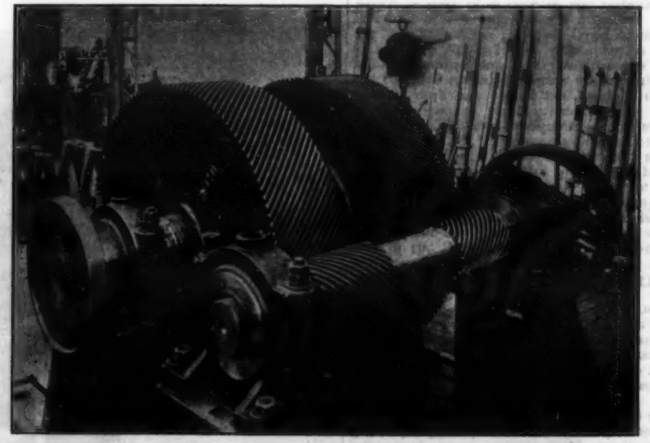


FIG. 4.

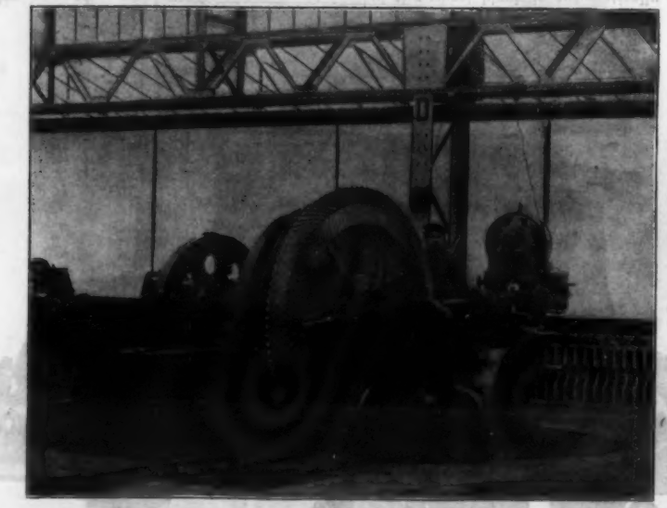


FIG. 5.

FIGS. 2 TO 5. EXAMPLES OF GEAR-CUTTING WORK IN PROGRESS AND FINISHED; THE CITROEN GEAR COMPANY'S FACTORY.

their standard 14½-deg. involute tooth and manufactured sets of milling cutters to suit. These cutters are of the disc type and are used in suitable milling machines, mainly automatic, which finish one tooth at a time. Very fine limits are worked to in the making of disc milling cutters, special machines being used to relieve the teeth, that is, to give cutting clearance, so that the cutter retains its shape after repeated sharpening so long as the teeth last. Eight cutters were originally used for each pitch, but to meet modern demands for greater accuracy of tooth shape 15 are used.

In the table on page 204 the whole numbers denote the original cutters, and the half numbers the new cutters. The cutters from 1 to 6½ are made to the smallest number of teeth in each range. In cutting other numbers than the smallest the effect is to thin the teeth at the point. This is not a serious error as it tends to a smoother action when working.

The disc cutter may be used for cutting spur and helical wheels and also worms, but, in cutting the last two, care must be taken in selecting cutters as a disc cutter in a helical groove does not cut its own shape. Given rigid cutting machines, with well-designed indexing apparatus and proper precautions to avoid errors due to temperature effects, the disc cutter produces excellent results. Used in a universal milling machine with a standard dividing head having a worm wheel or dividing disc of small diameter indifferent

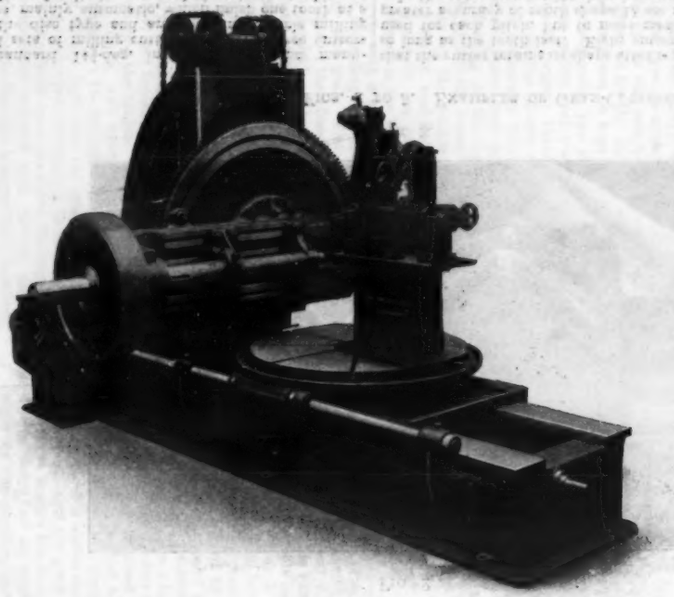


FIG. 6.

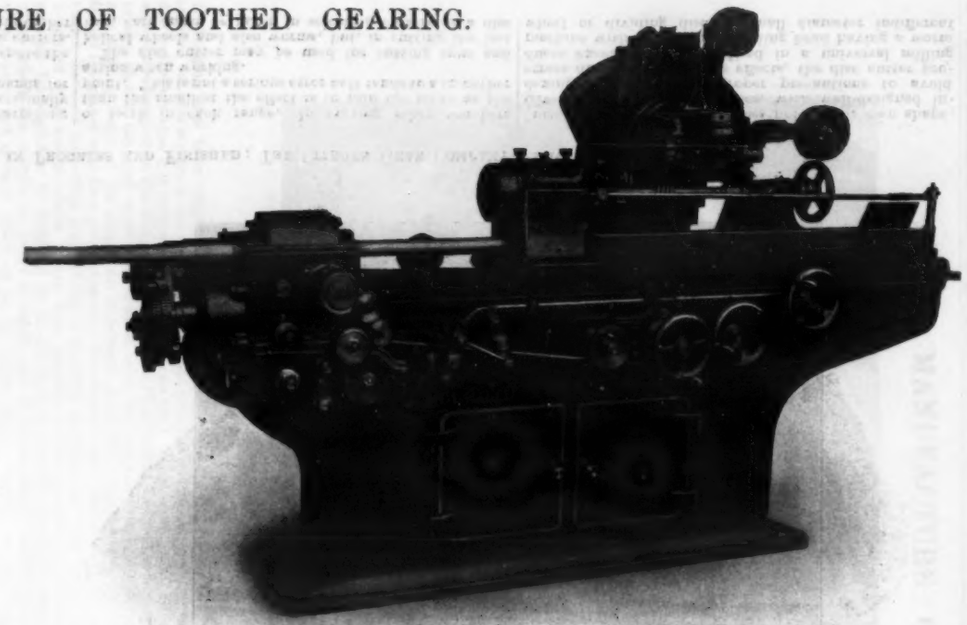


FIG. 7.

results may be expected.

No. 1	for wheels from	135	teeth to a rack.		
,, 1½	,, ,,	80	,,	134	teeth.
,, 2	,, ,,	55	,,	79	,,
,, 2½	,, ,,	42	,,	54	,,
,, 3	,, ,,	35	,,	41	,,
,, 3½	,, ,,	30	,,	34	,,
,, 4	,, ,,	26	,,	29	,,
,, 4½	,, ,,	23	,,	25	,,
,, 5	,, ,,	21	,,	22	,,
,, 5½	,, ,,	19	,,	20	,,
,, 6	,, ,,	17	,,	18	,,
,, 6½	,, ,,	15	,,	16	,,
,, 7	,, ,,	14	,,		
,, 7½	,, ,,	13	,,		
,, 8	,, ,,	12	,,		

Another milling process, which has been applied more particularly to double and multiple helical wheels or both spur and bevel type, uses end mills. This system has been highly developed by a French firm, the Citroen Gear Company. In making the cutters an exact drawing of the tooth is made, mating templates are fitted to the drawing and carefully tested for accuracy. The profile of the cutters is made to the templates, which are made for each individual wheel. Their machines, some photographs of which are shown, are capable of cutting a minimum pitch of ¼ in. and a maximum of 12 in. on a spur wheel 26 ft. diameter and 3 ft. wide.

These machines have cut helical gearing for French war and merchant vessels, rolling mills, hydro-electric plants, railways and motor cars. The wheel to be cut is carried on a horizontal spindle. The milling head, with suitable cutter driving gear, usually electrical, travels parallel to the pitch line of the wheel which is slowly revolving at a speed co-ordinated to the travel of the milling head. A helical groove is thus produced. When a multiple helical tooth is required the rotation

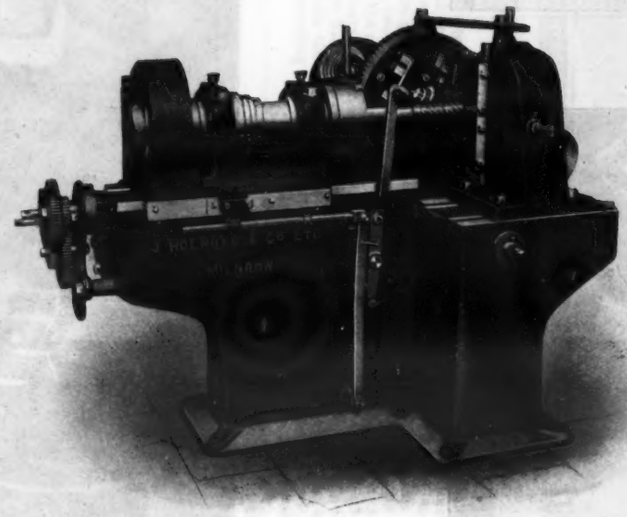


FIG. 8.

FIGS. 6 TO 8. GEAR-CUTTING MACHINES; MESSRS. J. HOLROYD AND CO., LIMITED, MILNROW.

of the wheel blank is automatically reversed without shock or loss of motion. The pointed apex at one side of the angle of the chevron is rounded off by a special device in the same machine. An example of a large machine is given in Fig. 1, page 202, and Figs. 2 to 5, page 203, show examples of work in progress and finished. The large pinion undergoing the cutting process is 5 in. pitch. Fig. 4 shows a set of turbine gearing mounted on a test bed.

Bevel wheels are cut, the bed on which the milling head slides being angularly adjustable to suit the bevel cone angle. The blank revolves and reverses, while the milling head travels as before. The groove which is cut on the conical surface is an equable or archimedean spiral. The tooth space may be formed by one cut, no touching of the sides is necessary. This is due to a property of the archimedean spiral. The shape of teeth obtained by these means is correct if the width of the face of the gear does not exceed one-third of the cone apex distance. The flexibility of this system as regard choice of helical angles is probably greater than most other systems as the cutters are easily produced and multiple helices can be used. Fig. 5, page 203, shows a bevel wheel undergoing the cutting process.

In all milling processes one tooth at a time is cut, necessitating for great accuracy a cutter for each number of teeth and special care in cutting to avoid inaccuracies of pitch due to temperature effects. In the hobbing process only one cutter per pitch is necessary and all the teeth in the wheel blank are undergoing the cutting process simultaneously. The cutter is in the form of a steel worm whose thread is broken up into teeth which are relieved as in the disc milling cutter, so that the grinding of the cutting face does not alter the profile, which is that of a rack of the required pitch. As an involute rack has a straight-line tooth profile, the production of the cutter is comparatively simple. The hardening of these cutters was at one time a cause of

THE MANUFACTURE OF TOOTHED GEARING.

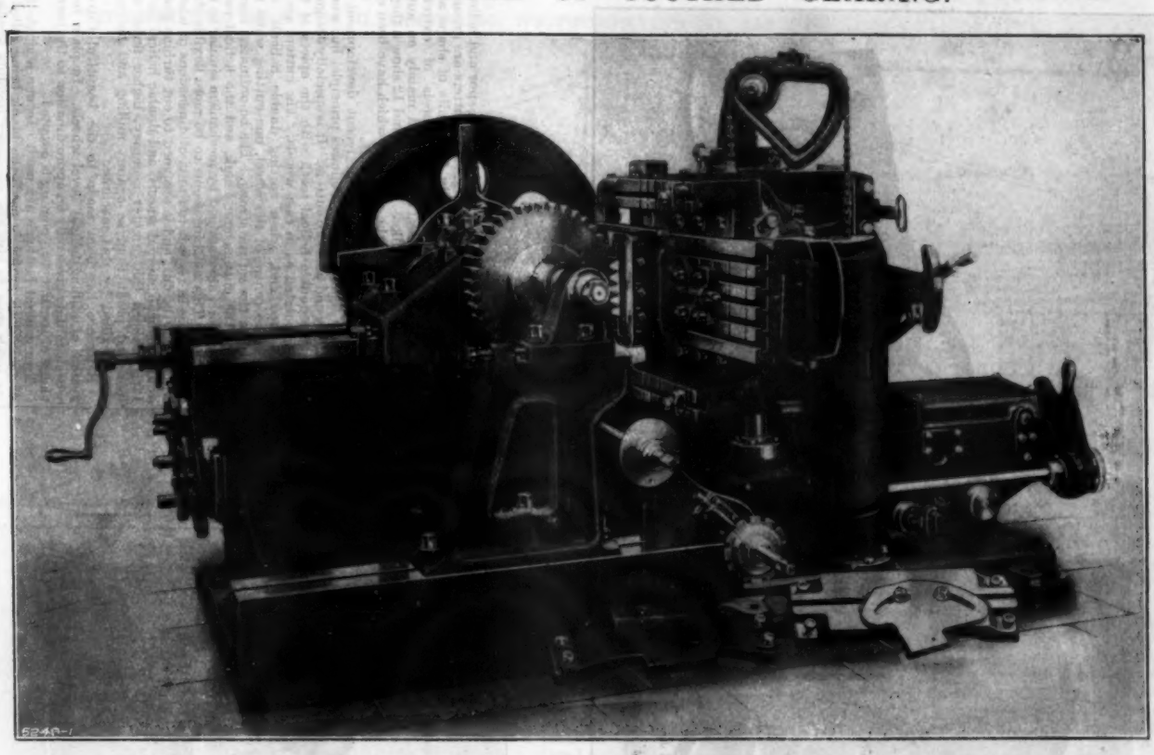


FIG. 9.

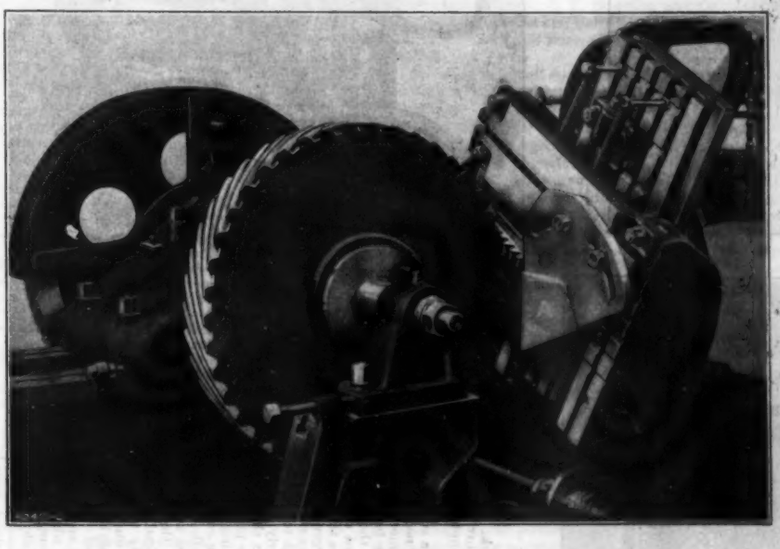


FIG. 10.

FIGS. 9 AND 10. SUNDERLAND SPUR PLANING MACHINES; MESSRS. J. PARKINSON AND SON, SHIPLEY, YORKS.

inaccuracy of final form, but modern manufacturers make the necessary allowances for hardening distortion, and by grinding after hardening, produce a hob, as this cutter is called, of great accuracy.

The hobbing process may be used for cutting plain spur wheels, single and double helical, and worms and worm wheels. The hob is geared positively in the desired ratio with the wheel which it cuts. In the case of a spur wheel the axis of the hob is inclined to the plane of the blank, an amount equal to the hob-thread angle. The hob is then set to cut the required depth and fed parallel to the axis of the blank, which is revolving at such a speed that if the hob is a single thread worm it makes as many revolutions for each revolution of the blank as there are teeth to be cut. The process is continuous, not intermittent like the milling process. The result is teeth of the correct profile and accurately spaced, providing the necessary preliminary setting of hob and blank has been accurately performed.

In cutting spur wheels the normal pitch of the hob must be equal to the circular pitch of the wheel, while in the case of worm wheels the axial pitch is equal to the circular pitch of the wheel. The hob is a substantial tool compared with the disc and end milling cutters, and the rigidly-designed hobbing machine is capable of fast production. Practical considerations of hob manufacture limit the pitch that may be cut by a hob to about 3 in. When a standard double helical gear is manufactured with a fixed helical angle of tooth, as in the Wuest system, special machines and hobs are used in order to produce extremely accurate wheels at reasonable cost. Two hobs, of right and left-hand thread respectively, are used, of such dimensions that the thread angle of the hobs is the complement of the corresponding angle of the gear teeth. This simplifies the construction of the hobbing machine and enables a powerful drive to be applied to the hob spindle and as the hob axis is always at right angles to the axis of the wheel blank the axial pitch of the hob is the same as the circular pitch of the wheel which it cuts. The hobs are placed diametrically opposite each other, one feeding up and the other down, the cuts meeting in the centre of the wheel. To save wheel width and to secure other advantages the wheel teeth in this system are usually "staggered," that is, a space on one side comes opposite a tooth on the other side of the wheel.

The Universal hobbing machine may be used to cut worms and worm wheels, but when large quantities of these are required milling by disc cutters is usually resorted to in the case of the worms, and cutting by means of tapered hobs in the case of the wheels. The disc milling cutters for cutting multiple-thread worms whose axial section is an involute rack, that is, a straight-sided thread, must have a rounded profile which varies with the angle of the worm thread and the pressure angle of the tooth form used. Fig. 6, page 204, shows a large machine capable of cutting wheels 10 ft. diameter, with a small machine for hobbing wheels 4 in. diameter.

Fig. 7 shows a worm-grinding and hob-sharpening machine, and Fig. 8 a worm-milling machine.

In the Lanchester worm-gearing system one machine is used which, in addition to generating its own hobs, cuts both worms and wheels. This gearing is a variation of the Hindley worm gearing, and is used mainly in automobile work. This machine, in spite of its multiple functions, is of simple construction. The action of the machine is the same whether used for generating its own tools or cutting either worm or wheel. The positions of work and tool are reversible, a worm hob cuts the wheel, a wheel hob cuts the worm, the spindles carrying each being geared together in the correct ratio.

Planing systems of generating tooth shapes are of two types. One uses a rack and the other a pinion as a cutter. The Sunderland system is of the rack cutter type. One cutter is used for each pitch. This is a short length of rack made of high-speed steel carefully ground, after hardening, in a machine which gives final accuracy to pitch and shape.

When cutting plain spur wheels the cutter is given a reciprocating motion across the face of the blank parallel to its axis. The cutter is fed gradually towards the blank until it reaches a position which gives the required depth of tooth space. Simultaneously between the strokes of the cutter the blank is given a rotary motion and the cutter traversed tangentially, these motions being co-ordinated so that the blank and cutter move as if the pitch line of the rack cutter

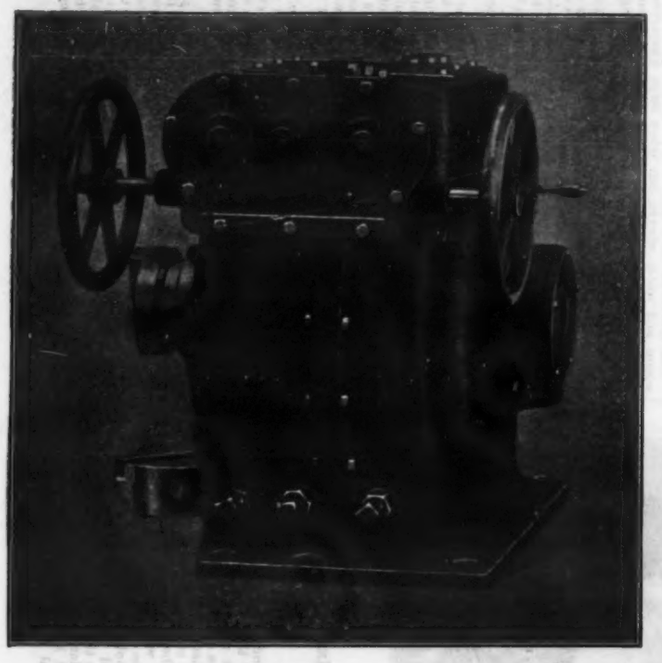


FIG. 11.

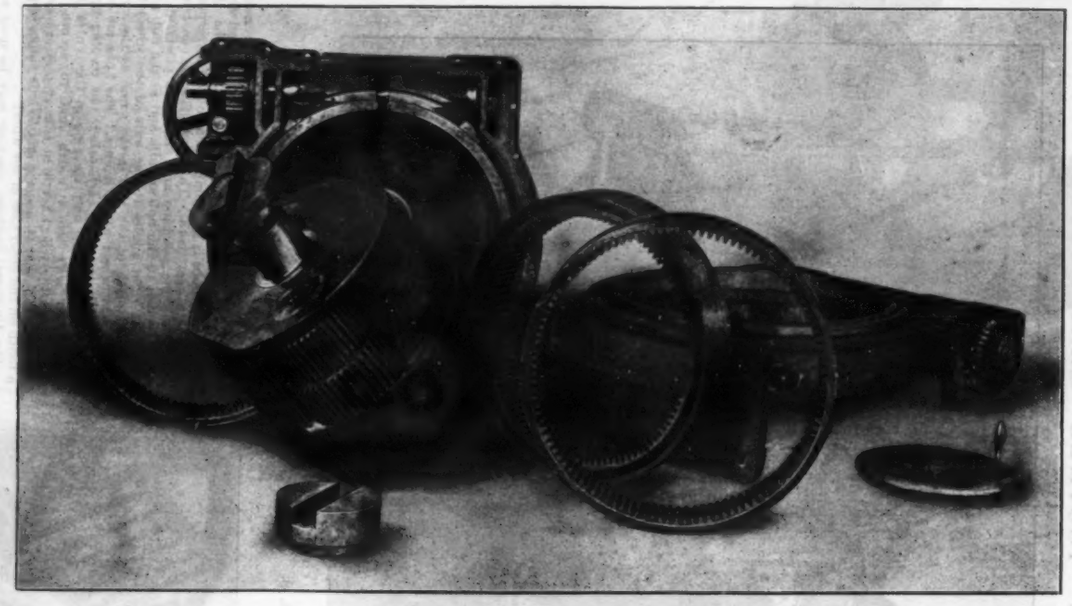


FIG. 12.

were rolling on the pitch line of the wheel blank. Given a sufficient number of teeth in the cutter, a little more than one revolution of the blank would complete the cutting operation.

As it is not practicable to use a cutter with a sufficient number of teeth, indexing or dividing is necessary. This is done automatically. After the rolling motion has operated through one pitch, the cutter steps back one pitch relatively to the wheel blank, and then the rolling motion recommences. This sequence is carried on until the blank is completed. In the smaller pitches the tooth spaces may be cut in one revolution, in the larger pitches more than one revolution may be required, depending on pitch, material to be cut, and accuracy of finish required.

Spiral or single helical gears are cut similarly, except that the cutter slide is set at right angles to the pitch cylinder of the developed helix. Fig. 9, on the preceding page, gives a general view of a planer cutting a plain spur wheel, and Fig. 10 the tool slide set for cutting a single helical wheel which is on the work spindle.*

In the Fellowes machine a pinion is used as a cutter. This is reciprocated parallel to the axis of the wheel blank, and is first fed radially to the required depth. The blank and the cutter are revolved slowly together in the proper ratio as determined by the number of teeth in each. The cutter thus forms in the blank in one revolution of the latter tooth spaces and teeth of the proper shape to mesh with itself, or with any wheel of the same pressure angle system. Helical wheels are cut by the aid of a helical guide fitted to the cutter slide so as to give the cutter a revolving motion while making its stroke. Internal wheels, both plain spur and helical, may be cut on these machines. The cutters are ground, after hardening, to extremely fine limits of shape and spacing. This system produces wheels of extreme accuracy in fine pitches, and is used mainly on automobile gears and the like. Figs. 11 and 12 show a three-speed reduction gear, the wheels of which have been cut on the Fellowes machine.

Another planing machine of recent development is the Sykes. This is on the Fellowes principle, but works horizontally and uses two cutters. It is specially designed for cutting double helical teeth with the apices of the chevrons pointed as in cast wheels. The cutters are of pinion shape and, when cutting double helicals, cut towards the centre of the wheel, one cutting while the other is on the return stroke. The co-ordinated movements of the cutters and blank, and the helical twist of the cutters, are obtained by mechanism similar to the Fellowes. This machine seems to be more flexible than the Fellowes in respect to limits of dimensions of wheels which may be cut, and is designed to cut turbine gears, double helical internal wheels, and double helical racks. It is claimed that greater accuracy, higher finish and increased production, as against milling and hobbing, are obtained by this machine.

Reference has been made to the beautiful Citroen system of milling helical bevel wheels. In plain bevel wheels milling gives only an approximation to the correct shape of tooth, hence planing is adopted.

Two general methods are used. In one a single tool of rack-tooth profile is used, the blank being rolled on its pitch cone to give the necessary involute profile to the tooth. In the other two pointed tools whose paths converge to meet at the pitch cone apex are used. The first method is much used in America and on the Con-

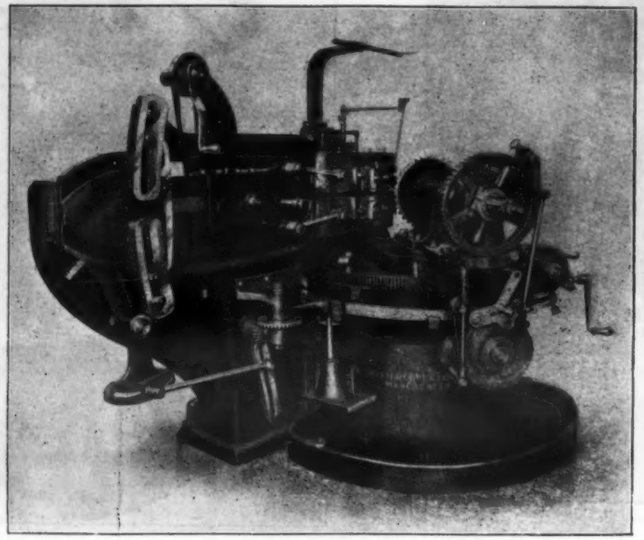


FIG. 13.

* A very full description of the Sunderland spur planing machine is given in the issue of ENGINEERING for December 14, 1917, page 617.

THE DOUBLE-REDUCTION GEARED TURBINE STEAMER "MERIDA."

CONSTRUCTED BY SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED, NEWCASTLE-ON-TYNE.

Fig. 1.

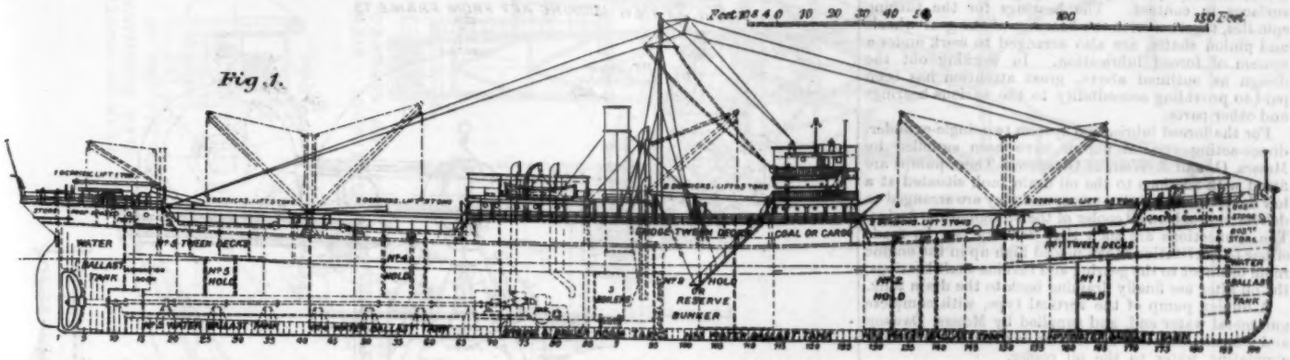
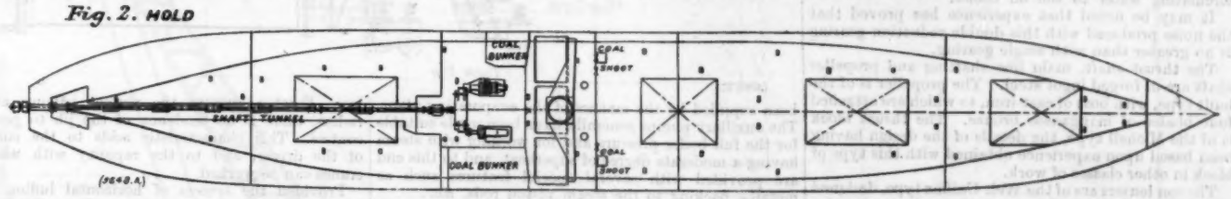


Fig. 2. HOLD



tinent. The Bilgram, an American machine, and the Monneret, a French machine, are examples of the first method. The Monneret machine is sometimes constructed so as to produce a single helical bevel.

The Robey-Smith planer is an example of the second method. Its two tools act on opposite sides of one tooth, and are guided in such a way that a very close approximation to a perfect involute tooth is produced. The work spindle is horizontal and the slide which carries it together with the indexing apparatus has a swivelling motion on an axis which is vertically below the converging point of the slides guiding the cutting tools. The tool slides have also a swivelling motion on their converging point as an axis. This point is really the apex of the pitch cones of the wheels which the machine cuts. The dividing arrangement operates once per double stroke of the tools. The tooth spaces are first roughed out with the converging tool slides fixed at an angle proportionate to the developed pitch angle of the blank operated on. The work spindle is fed towards the tools once per revolution of the blank. In the finishing process the converging tool slides are free to swivel on their pivot points. The feed motion of the work spindle and the variation of the angle between the tool slides are co-ordinated by an arrangement of linkwork and gearing, in such a manner that as the work spindle approaches the tools the space between them is increased in the ratio required to give the involute profile to the tooth and the necessary lengthwise taper. Using two tools this machine combines accuracy with rapidity of production. This machine is shown in Fig. 13.

Wheel teeth-cutting machines are full of intricate detail which would take volumes to describe. The differential gear in hobbing machines and the creeping table for averaging the errors in indexing or dividing worm wheels are examples. The advent of turbine gearing has led to increased accuracy. The maximum error between adjacent teeth in the cutter for one of the planing machines described is less than 0·004 in. Machines are carefully designed for rigidity and adjustment for wear, but as accuracy of finished product depends on the proper working of the machine by the user, machine makers are reluctant to specify limits of accuracy which may be affected by causes beyond their control. Very careful supervision of teeth-cutting operations enables accurate work to be carried out on machines that are not fitted with refinements such as the creeping table; refinements are useless without this supervision.

(To be continued.)

PIG-IRON SHIPMENTS FROM MIDDLESBROUGH.—According to a circular issued by Messrs. William Jacks and Co., the shipments of pig-iron from Middlesbrough, including Skinningrove, in January last were 1,370 tons coastwise, 30,011 tons to foreign countries (the principal buyers being France and Italy), making a total of 31,381 tons, as compared with a total of 28,513 tons for December, 1918.

THE INDUSTRIAL RECONSTRUCTION COUNCIL.—The fourth lecture of the series arranged by the Industrial Reconstruction Council will be held in the Saddlers' Hall, Cheapside, E.C. 2, on Wednesday, the 19th inst. The chair will be taken at 4.30 by the Right Hon. Lord Leverhulme, and a lecture on "The Responsibility of Trade Unions in Relation to Industry" will be delivered by the Right Hon. J. R. Clynes, M.P. Applications for tickets should be made to the Secretary, Industrial Reconstruction Council, 2 and 4, Tudor-street, E.C. 4.

DOUBLE-REDUCTION GEARED TURBINES FOR S.S. "MERIDA."

ON Plate XI and on this and the next pages we illustrate geared turbine machinery constructed by the Wallsend Slipway and Engineering Company, Limited, Wallsend-on-Tyne, and installed by them on board the S.S. Merida which is a vessel of the single-screw type having its machinery placed amidships. The Merida, of which a longitudinal section and a plan are reproduced in Figs. 1 and 2, above, was built by Messrs. Sir W. G. Armstrong, Whitworth and Co., at their Walker shipyard, for Messrs. C. T. Bowring and Co., Limited, of Liverpool, London and Cardiff, under the supervision of Messrs. Jacobs and Barringer, of Gracechurch-street, London.

The vessel is a well designed modern cargo steamer, the length overall being 435 ft., between perpendiculars, 420 ft., breadth extreme, 55 ft. 3 in., and she carries about 9,100 tons on a draught of about 25 ft. The general arrangement is clearly shown on the drawings. Special attention has been paid to the loading and discharging arrangements, and the sizes and disposition of hatches and cargo gear are calculated to reduce as far as possible the idle time in port. Owing to war time requirements, the original rigging plan had to be considerably altered, and the signal mast and hinged derrick poles, which have become a feature of war time cargo vessels, were substituted for the more normal arrangement which was originally contemplated. Accommodation is provided for the crew in the forecastle; officers and engineers in houses on the bridge; gunners, petty officers, carpenters, cooks, &c., in the poop. The accommodation generally is on a generous scale, and is well adapted for the requirements of the personnel on a modern cargo steamer. Water ballast is carried in the double bottom and peaks.

The propelling machinery consists of three turbines working in series and driving the propeller shafting through compound or double reduction gearing. This turbine machinery has been designed to develop about 2,000 shaft horse-power, under ordinary service conditions, and by the adoption of the double gearing the revolutions of the propeller for the given power will never exceed those which would be adopted for a similar single-screw vessel fitted with reciprocating engines. As this two-step system of gearing makes possible speeds of revolution respectively best suited both to the turbines and to the propeller, an overall efficiency has been attained which is probably higher than that of any other type of propelling machinery for this class of vessel. This advance as regards economy has not been obtained by introducing complications or additions to the machinery installation, that will call for any increase in the engine room personnel, or will produce any further tax upon the usual staff in supervising the machinery, so that the fuel saving effected really implies a true net gain in the earning capacity of the vessel.

The general arrangement of the machinery is clearly shown in Figs. 3 to 6, Plate XI. As stated above, there are three turbines working in series. The high-pressure turbine runs in tandem with the intermediate turbine, and together they operate one of the first reduction pinions, while the low-pressure turbine operates a similar pinion on the opposite side of the large wheel, as shown in the end view, Fig. 9, page 208.

The Brown-Curtis type of turbine has been adopted, having, as shown in Figs. 7 and 8, Plate XI, wheel stages throughout, the grouping of which is such as to produce practically an equal transmission of power through each of the shaft pinions. For going astern there are two turbines working in series, and incorporated respectively with the intermediate and low-pressure turbines, as shown. As there are thus two astern turbines which work in series, a higher efficiency is realised, and as each can, in an emergency, be operated separately, there is less risk of a total breakdown as regards going astern, than if the astern turbines had been arranged to drive the low-pressure shaft only. With a view to obtaining the highest possible economy, superheated steam is employed, this has necessitated the use of cast steel and phosphor bronze for various details which are in contact with the steam at its highest pressure and temperature. The blading throughout is made from phosphor bronze. The rotating portions of the turbines, comprising the wheels and the spindles, have been made entirely from ingot steel forgings.

Special attention has been given to the arrangement of pipes and valves for the main and emergency steam supply to the turbines, the shut-off and manœuvring valves being supported from the engine-room forward bulkhead, being placed high up near the level of the boiler stop valves. The starting platform is fixed some few feet above the tank top, to suit the general arrangement of machinery, the spindles from the manœuvring valves being led down and having the hand wheels placed at a suitable height for operating. The revolution counter and pressure gauges are grouped on a stand adjacent to the starting position. Emergency governors of the Proell type are driven from the forward end of the high-pressure and low-pressure turbines. Steam strainers are provided on the initial steam admission branches to the high-pressure ahead and astern turbines, and also on the exhaust connections between the high-pressure and low-pressure turbines.

As previously noticed, the arrangement of gearing is of the double reduction type, the total reduction of speed between the turbines and the propeller being effected in two steps. The pinions of the first reduction gearing are driven from the turbine shafts through flexible couplings, which allow for any want of alignment of the shafts or take up any movements due to want of rigidity of the seatings. The gearing is of the usual double helical type. The wheels for both the first and second reduction trains have their central portions or bodies made of cast-iron; the rims upon which the teeth are cut are made from forged ingot steel, and are shrunk on their centres and securely fixed. The pinions for the first and second reduction are respectively made of nickel steel and high carbon steel. The main gear wheel shaft is of forged ingot steel, provided with a solid flanged coupling, directly connected to the thrust shaft. For the efficient and

silent running of such gearing it is necessary that the lubrication should be thoroughly effective. For this purpose sprayer nozzles distributed at suitable intervals are arranged to spray the oil direct on to the engaging teeth, thereby providing a film of oil between the surfaces in contact. The bearings for the turbine spindles, together with the bearings of the gear wheels and pinion shafts, are also arranged to work under a system of forced lubrication. In working out the design as outlined above, great attention has been paid to providing accessibility to the various bearings and other parts.

For the forced lubrication system two single-cylinder, direct-acting vertical pumps have been supplied by Messrs. G. and J. Weir, of Glasgow. These pumps are fitted with suctions to the oil drain tank situated at a low level in the engine-room, and they are arranged to deliver through an oil cooler of the straight-tube design. The connections are such that delivery can be made either to gravitation tanks placed high up in the engine room or direct to the gearing and turbine shaft bearings, the oil after use finally draining back to the drain tank.

A duplex pump of the vertical type, with complete gun-metal water end, and supplied by Messrs. Dawson and Downie, Limited, Clydebank, is fitted for providing circulating water to the oil cooler.

It may be noted that experience has proved that the noise produced with this double reduction gearing is no greater than with single gearing.

The thrust shaft, main line shafting and propeller shaft are of forged ingot steel. The propeller is of the built type, with boss of cast-iron, to which are attached four blades of manganese bronze. The thrust block is of the Michell type, the details of the design having been based upon experience obtained with this type of block in other classes of work.

The condensers are of the Weir Uniflex type, designed to secure 27½ in. of vacuum in ordinary service conditions with the temperature of sea water at 80 deg. Fah. In the arrangement of machinery it was found possible to place the condenser at a low level, and at the same time quite close to the low-pressure turbine, which simplifies the drainage problem, and also does away with the usual exhaust connection. For circulating water through the main condenser, a pump of the centrifugal type is provided. This pump can be driven by either of two independent, single-cylinder, open-type engines which, together with the pump, have been supplied by Messrs. Drysdale and Co., Limited, Glasgow.

An air pump of the Dual type, as supplied by Messrs. G. and J. Weir, Limited, is fitted to work in conjunction with the condenser. The air pump is of the merchant-service type, having gun-metal pump barrels with cast-iron bases and tops, fitted with gun-metal buckets, manganese bronze pump rods, steel piston rods and Kinghorn valves in gun-metal seats. The feed pumps consist of three single-cylinder direct-acting vertical pumps, each pump being capable of delivering the necessary feed water under ordinary service conditions. The water ends of the pumps are entirely of gun-metal, fitted with gun-metal liners, gun-metal buckets, manganese-bronze rods and bronze valves in gun-metal seats. The feed water is delivered by the feed pumps through one surface feed-water heater of the multiflow type, which is arranged to utilise the steam from the auxiliary machinery. The shell of the feed heater is of close-grained cast-iron and fitted with solid-drawn copper tubes. The whole of this plant was supplied by Messrs. G. and J. Weir. A feed-water filter of the gravitation type, made by the North-Eastern Marine Engineering Company, Limited, Wallsend, is fitted, the filter tank being provided with the necessary float gear for controlling the feed pumps. The main air pumps are arranged to deliver the feed water to this filter tank, and the feed pumps to draw therefrom.

The auxiliary condenser is of the ordinary design, with cast-iron body of circular section. It is of sufficient capacity to deal readily with the exhaust steam from the whole of the auxiliary pumps, &c., electric-lighting plant, winches and deck fittings. It is of the non-vacuum type, and is arranged to drain to the filter tank.

Other auxiliary machinery forming part of the complete engine-room installation includes a service donkey for general purposes of the vertical duplex type, with complete gun-metal water end, this pump being also arranged to deliver to deck for sanitary purposes. A large ballast pump of the vertical duplex type is fitted for dealing with the water ballast carried in the double-bottom tanks. The two bilge pumps are worked from the gear-wheel shaft, one of these being arranged to draw from the sea and deliver into the wash-deck pipe and sanitary tank.

The evaporating plant, fitted by the machinery contractors, consists of one evaporator supplied by Messrs Davie and Horne, Limited. This is of the merchant-service type and is capable of evaporating 30 tons of water per day of 24 hours when supplied with direct boiler steam. For feeding the evaporator a vertical pump of the simplex low-service type is fitted; this has been supplied by the makers of the evaporating plant. The auxiliary pumps generally have been made suitable for the full boiler pressure and for working with steam having a moderate degree of superheat, and to this end are provided with several special features such as metallic packing to the steam piston rods, &c.

The boilers are of the multitubular, single-ended type, two in number, each 16 ft. outside diameter and 11 ft. long, with three Morison furnaces. They are constructed for a working pressure of 220 lb. per square inch, and will be operated under natural draught.

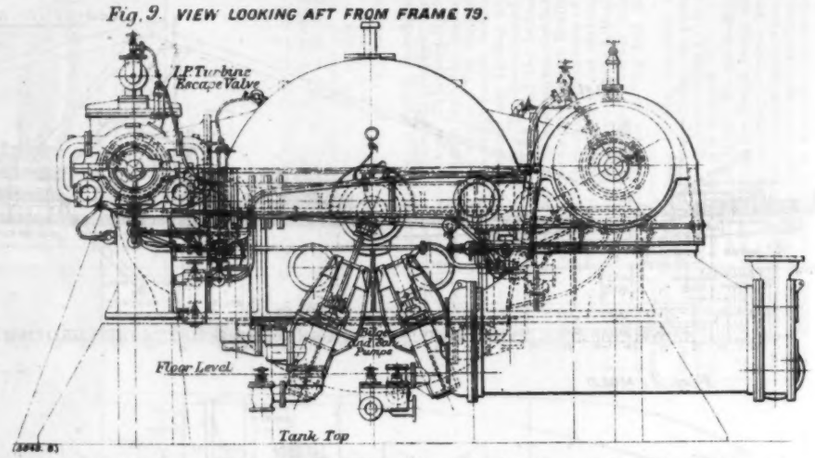
Superheaters are fitted to the boilers, the special fittings for these having been supplied by the North-Eastern Marine Engineering Company, Limited, Wallsend-on-Tyne. The amount of superheat contemplated is about 200 deg. F. at the boilers. Diamond blowers are fitted to the back of each combustion chamber with steam connections complete. Both boilers discharge into a single circular-shaped chimney, the height of which above the grate is about 70 ft. For disposing of the ashes an ash hoist was supplied by Messrs. Railton, Campbell and Crawford, Limited, Liverpool.

Considerable attention has been paid to economising radiation and convection losses throughout the whole plant. The turbines are cleaded with an inner layer next the walls of asbestos fibre-filled matresses 1½ in. thick, this is followed by an air space, which is covered by the outer layer of magnesia blocks 2 in. thick, the whole being cased with planished steel sheets secured with polished steel bands. The steam cylinders of all auxiliaries except those for the ash hoist are covered with 1½ in. of magnesia or similar composition placed direct on the castings, then an air space, followed by 1½ in. of asbestos mattresses, the whole being covered with planished sheet steel. Steam valve chests and all exposed steam surfaces are covered with good non-conducting composition and cased in with planished sheet steel.

DOUBLE-REDUCTION GEARED TURBINES.

THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, WALLSEND-ON-TYNE.

Fig. 9. VIEW LOOKING AFT FROM FRAME 79.



[3848 E]

4-TON "TOPLIS" LUFFING CRANES FOR SHIPYARDS.

The application of horizontal luffing cranes of the jib type to services of a general character, especially with regard to the handling of cargo, having proved a marked success, it follows that their use for the purposes of shipbuilding is only a natural consequence.

Messrs. Stothert & Pitt, Limited, of Bath, have recently specially designed some cranes of this type for shipyard use, and although we have in our issue of June 26, 1914 (vol. xcvii, page 874), described the principle of the Toplis luffing and balanced jib mechanism, and in a subsequent number, that of September 24, 1915 (vol. c, page 306), described a 10-ton crane installed in Hills' Dry Dock and Engineering Company's yard at Cardiff, the subject is of such importance that we now give particulars of an interesting application of this type of crane in a shipyard.

The Toplis system of horizontal luffing is well known; a prominent feature of this gear is its mechanical simplicity, together with the advantages obtained by the introduction of the balanced jib. Owing to the balance of the jib, the movements of the latter are exceedingly responsive to the controller handle, and render the manipulation, even at high speeds, a comparatively simple matter. The speeds of luffing may be considerably increased, and at the same time the power absorbed in luffing the jib and load is remarkably low. Further, due to the perfect balance at every radius, there is no tendency of the jib to get out of control. This characteristic adds to the confidence of the driver, and to the rapidity with which the cranes can be worked.

Provided the system of horizontal luffing can be obtained without any corresponding disadvantages such as complexity of design, the predominant advantages of cranes so fitted over those of the non-horizontal type may be summarised as follows:—

1. Simple control and consequent induced confidence of the operator.
2. Rapidity of working.
3. Lower power consumption.
4. Safety, owing to there being no tendency for the jib to take charge.
5. Reliability.

It will be readily understood that if advantages such as these can be indisputably established, they are characteristics which will make a very strong appeal to shipbuilders.

During the past few years a number of cranes of the cantilever type have been installed in British shipyards, and there is a tendency to perpetuate this practice at the present time. In considering the advantages of the jib type in contradistinction to the cantilever type, the following points should be noted:—

Assuming that the cranes are of the fixed type, and that the radii of the several cranes in plan cut each other—which is the usual practice—it will be necessary to make the cantilever towers of different heights in order that there shall be no danger of the cantilever jibs fouling each other during the operation of slewing. With the jib type of crane, the heights of all the towers can be similar, viz., the minimum height necessary, as the jibs can be simply and rapidly adjusted to clear obstacles, so that there is no danger of fouls when slewing. Again, the power absorbed in slewing the cantilever jib is always the maximum amount, even if the load is only being carried at the minimum radius, and it is well worth observing that the power necessary to slew the jibs of this type in high winds may rise to a surprising figure. Conversely, when the wind is assisting the slew, the jibs are liable to get out of control, owing to the large wind-turning moment produced. With the jib type of crane, the jib is adjusted to suit the radius at which the load is being worked, and the power required for slewing is correspondingly reduced to a minimum. Then, again, the load with the cantilever type of crane is almost invariably lifted on a snatchblock with two falls of rope, as this conduces towards a simple mechanical arrangement of the hoisting machinery. This is a serious disadvantage from the standpoint of handling, and particularly so with regard to the danger of twisting up of the falls. With the jib type of crane, the load is lifted on a single fall, which gives the maximum convenience for handling and automatically eliminates the danger of twisting, and the attendant disadvantages. There is still one other point which may be mentioned to the credit of the jib crane, viz., that the latter crane, owing to the capability of adjustment of the jib, will give a maximum amount of clearance under the jib, with the latter at radii smaller than the maximum, and a clearance greatly in excess of that given by a cantilever crane of similar dimensions. This is distinctly useful on occasions when loads of a special nature have to be handled.

Assuming now that the cranes are of the travelling

4-TON "TOPLIS" LUFFING CRANE FOR SHIPYARDS.

CONSTRUCTED BY MESSRS. STOTHERT AND PITT, LIMITED, ENGINEERS, BATH.

(*For Description, see opposite Page.*)

Fig. 1.

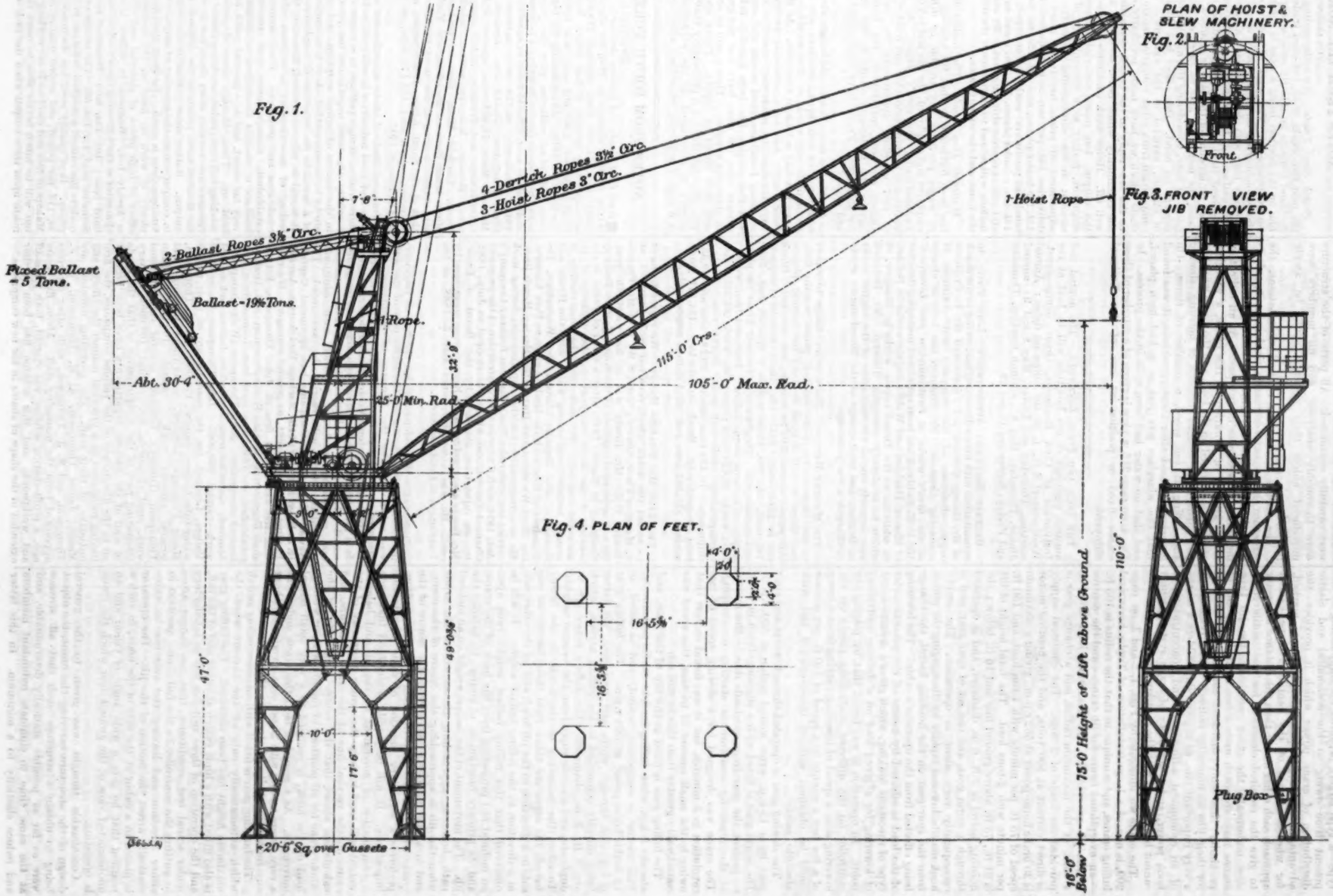


Fig. 2. PLAN OF HOIST & SLEW MACHINERY.

Fig. 3. FRONT VIEW JIB REMOVED.

Fig. 4. PLAN OF FEET.

type—a type largely favoured for shipbuilding at the present time owing to the economical and elastic distribution of crane power which it provides—the advantages of the jib crane are still more marked, for whereas cranes of the cantilever type cannot approach each other nearer than the distance necessary to give the required clearance for one cantilever to slew underneath the other cantilever, the jib type cranes may approach each other to such a point of proximity that only sufficient clearance is allowed for their jibs at minimum radius. This advantage is a very important one, as it gives shipbuilders a means of an economical adjustment and concentration of hook power, and a flexibility of crane system, which cannot be obtained with the cantilever type.

The crane we illustrate by Figs. 1, 2 and 3, on page 209, is one of a large installation of Toplis horizontal luffing cranes, and is unique in that the radius is 105 ft. —an exceptional figure for jib cranes—and the centres of the jib are 115 ft. The maximum load lifted is 4 tons, at the maximum radius, and a change gear is provided for loads of 2 tons. The electrical supply is direct current at 500 volts, and the hoisting motor is 30 brake horse-power at 552 r.p.m., giving a maximum speed of 75 ft. per minute with 4-ton load, and 150 ft. per minute with 2-tons load. The total height of lift is 91 ft., 75 ft. above ground line and 16 ft. below; the hoisting barrel is 2 ft. 6 in. diameter, and is operated through a worm gear, and one set of spur gear, and is consequently very silent in operation. The empty hook may be lowered rapidly by disengaging the pinion from the spur gear on the hoisting barrel, the change being effected from the operator's cabin. The lowering of the load is effected by means of the potentiometer type of rheostatic braking, which gives a definite speed of lowering for a given load on a definite controlling point. In operation it was found that by placing the controller on the different controlling points on the lowering side, a speed of lowering varying from a creep of a few feet a minute to a speed of 150 ft. per minute could be obtained without inconvenience and with absolute safety.

The slewing gear is operated through worm and spur gear by a 15-h.p. series wound motor at 520 r.p.m. The worm gear is fitted with a slipping clutch in order to protect the gear from overloads due to the inertia of the revolving structure in starting or stopping. The crane was designed for a slewing speed of one revolution in 3 minutes, but it was found on test that owing to the small amount of friction, this speed was considerably greater than this in still air.

The luffing gear is fixed at the top of the mast, and absorbs 8 h.p. when luffing load at 80 ft. per minute. This motor is compound wound, and is rated at 12 brake horse-power at 520 r.p.m. The luffing gear is operated through worm and spur gear, the latter being directly connected to the luffing barrels, which are 2 ft. 9 in. diameter. The luffing ropes are in duplicate, and also the ropes from the balance weights. To effect the balancing of the loads on the luffing barrels the ropes are taken from these barrels on one side in a direction to the jib head, and on the other side in a direction to the rolling ballast weight. It will be observed that this rolling ballast weight runs upon an inclined rail projecting from the back of the crane, and its primary function is, of course, to balance the jib. The movement of the ballast weight on an inclined path, however, approaching the centre of the crane when the jib is approaching the centre of the crane, and in a like manner receding from the centre of the crane when the jib is performing a similar motion, performs a secondary function of some considerable importance. It will be readily understood that such a combination of movement of the jib and balance weight will tend to keep the centre of gravity of the crane on the vertical line of the crane structure, and calculation shows that the centre of gravity of the whole crane for all positions of the jib, with or without load on the hook, is confined to a very small lateral movement. As a record of fact, this crane underwent a very severe testing with 25 per cent. overload without any foundation bolts whatever in the base.

The hoisting gear is fitted with an overwinding switch which automatically cuts off the current when the maximum height has been obtained. The luffing gear is also fitted with a limit switch at either end of the luff, and the operation of these switches was so satisfactory under actual test conditions, that no danger arose in putting the controller to the full "on" position in either direction and leaving the switches to automatically arrest the motion of the jib. The operator is placed in a cabin at the side of the mast, in such a position that he gets a wide angle of vision and an unobstructed view of the ground over which the crane is operating.

Considerable thought was given to the general design of the structure carrying the crane, the object being to obtain a structure such that all stresses were as far as possible statically determinable, and at the same time to eliminate redundant members and reduce elasticity to a minimum. In this latter connection the probable effect of secondary stresses were carefully considered. All parts of the structure were thoroughly analysed, and no members were introduced unless their presence could be amply justified.

The results more than realised expectations, the structure being extraordinarily rigid in spite of its general appearance of lightness, and there was no indication of weakness in any part. As an indication of the absence of vibration on this crane, a wineglass of water was placed on the load, and the crane was then put through its various motions of hoisting, slewing and luffing at full speed, a number of times. On lowering the load after these operations, it was found that the wineglass was just as it had been placed, and that no water had been spilt in the process. In Fig. 4, on page 212, a view is given of a number of these cranes fixed in position at one of the National Shipyards.

The Iron and Steel Institute.—The annual and autumn meetings of the Institute will be held at the Institution of Civil Engineers, Great George-street, Westminster, S.W. 1, on the following dates: Annual meeting, Thursday and Friday, May 8 and 9; annual dinner, Thursday, May 8; autumn meeting, Thursday and Friday, September 18 and 19.

Belfast Shipyard Appointment.—Lord Pirrie, in consultation with his co-directors, has, owing to the death of Mr. George Cuming, J.P., appointed Mr. R. Crighton deputy-chairman of the company and chairman of managing directors. Mr. Crighton has been in charge of the firm's works in Southampton and Liverpool. Mr. F. E. Rebbeck has been appointed managing director of Messrs. Harland and Wolff's engine works in Belfast, in addition to the Diesel engine works in Glasgow, of which he is already managing director. Mr. Rebbeck was formerly one of the managers of the engine works in Belfast, and took charge of the Diesel engine works in Glasgow a few years ago.

Tin Market Report.—There is no change to report in the Swansea tin plate market, prices remain firm, and there is still a good demand for prompt plates. Galvanised sheets, 24G in bundles, are nominal. Block tin is 226*l.* cash, 223*l.* 15*s.* three months; copper, 79*l.* cash, 70*l.* 10*s.* three months; Spanish lead, 29*l.*; and spelter, 48*l.* The Swansea Harbour Trust tin plate shipment returns are as follow: Received from works: Last week, 33,624 tons; previous week, 44,755 tons; corresponding week last year, 20,124 tons. Week's shipments: 10,435 tons, against 29,281 tons and 29,367 tons respectively. Stock at docks: 154,771 tons, against 131,582 tons and 166,476 tons respectively.

The late Mr. Francis Brady.—We regret to have to record the death which occurred on February 1, at 1, Mansion Place, Queen's Gate, S.W. 7, of Mr. Francis Brady, C.E. Mr. Brady was in his ninetieth year. He was appointed engineer of the South-Eastern Railway Company in March, 1870, after a term of years in the service of the same company in the capacity of an assistant engineer. He undertook the construction of several branch lines, among which were the Hythe and Sandgate, the Bromley direct, the Westerham, the Hundred of Hoo with the landing stage at Port Victoria, the West Wickham and Hayes, the Bexley Heath lines. He was responsible for the experimental boring work carried out under the South-Eastern Railway Company's Act, 1874, with a view to the construction of the proposed Channel Tunnel, and which was stopped in July, 1882, by an injunction obtained by the Board of Trade. Mr. Brady also conducted, in Kent, boring operations for coal. He was a member, since May 5, 1868, of the Institution of Civil Engineers.

Personal.—We understand that the Newall Engineering Company, which, during the latter part of the war, was taken over by the Ministry of Munitions, and operated as a National Gauge Factory, has now reverted to its former proprietors, Messrs. Peter Hooker, Limited. It is understood that the company intends to reorganise and develop its pre-war business in gauges, micrometers, and measuring machines, together with additional specialities which will shortly be announced. The Newall Engineering Company has appointed Captain R. J. Bray, Director of the Machine Tool Section, Aircraft Production Department, as general manager.—We note that the well-known firm of John Thompson, Ettingshall Engineering Works, Wolverhampton and Dudley, established in 1840, has now been formed into four limited companies: John Thompson (Wolverhampton), Limited, manufacturing Lancashire boilers and welded work—capital, 230,000*l.*; John Thompson, Water-Tube Boilers, Limited, for the manufacture of their patent water-tube boilers—capital, 170,000*l.*; John Thompson, Motor Pressings, Limited, motor-frame pressings and general pressed work — capital, 100,000*l.*; John Thompson (Dudley), Limited, general constructional work, steel chimneys, &c.—capital, 100,000*l.* A very interesting part of the reorganisation is that the heads of staff of the various departments have been brought on to the directorate of the various companies, the firm having recognised in a practical manner the efforts and initiative of their staff. The governing directors are Messrs. James Thompson, A. E. Thompson, W. J. Thompson, and S. J. Thompson, with other directors appointed from the managing staff. About five years ago, a profit-sharing scheme was started, both for staff and workpeople, and this scheme has been further extended in the shape of shares in the new companies.

NOTES FROM THE NORTH.

Glasgow, Wednesday.

Scotch Steel Trade.—Notwithstanding the events of the past two weeks or so, the steel trade in the West of Scotland remains on a fairly satisfactory basis, the only blot on the horizon being a want of confidence regarding future prospects. The work of reconstruction requires the wholehearted services, not of employers alone, but of every man who claims to have a patriotic interest in the welfare of the country. Unfortunately, two of the local steel works were obliged to close down last week on account of the labour troubles, but in all other cases the men were able to carry on much as usual, a point of note, considering the number of good orders at present on hand. One effect has been a distinct fall of output, harmful in the extreme. The threatened competition from other countries, anxious to secure the trade which we have made peculiarly our own should be the best reply to the foolish demands of a section of the community which never seems to know when it is well off. Home work continues to absorb the bulk of the output, but more material is now available for shipment, mainly as a consequence of the disturbing element in the shipbuilding industry. A further re-adjustment of prices has taken place, and for home deliveries 14*l.* per ton is now quoted for ship plates, 15*l.* for boiler plates, and 13*l.* 12*s.* 6*d.* for angles—all in trucks at producers' works. For export, ship plates are 16*l.* 10*s.*; boiler plates, 17*l.* 10*s.*; and angles, 16*l.* 2*s.* 6*d.*, all f.o.b. at nearest shipping port. By arrangement, steel makers will refund to Government the difference between the home and the export rates.

Malleable Iron Trade.—The malleable iron industry has been fortunate in that the existing system relative to wages prevents any trouble or difficulty between employer and employed, the rise and fall of prices settling automatically, the men's wages. As a consequence, business is running smoothly and briskly, a better supply of fuel affording opportunity for increased output. Orders are well maintained, the home market still having the preference owing to the prohibitive rates for shipment. Prices have been raised both for home and export.

Scotch Pig-Iron Trade.—Although the furnaces have continued in full blast, smelters are still unable to accumulate any stock, so that would-be export buyers have not had a look-in even yet. At the same time a freer supply has been available during the past few days through the temporary cessation of operations in so many foundries, steel works and engineering shops, and this surplus has been greedily taken up by consumers who, till now, have had the greatest difficulty in obtaining supplies. Thus it will be seen that demand still runs ahead of supply. Prices are unchanged as yet, although there is a probability that an increase will shortly be announced, as the adjustment of subsidies is a matter requiring immediate attention.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Hull Coal Trade.—A further decline is recorded in the return of coal imports to Hull for January last. The total was 174,970 tons, against 218,667 tons in the corresponding month of last year. For the year the total imported, 2,605,602 tons, was 206,754 tons below the total for 1918. As instancing the big fall in receipts from individual collieries over the year as compared with the former twelve months, it is noted that Denaby and Cadeby sent 229,045 tons, as against 301,208 tons in 1917; Bullcroft, 85,120 tons, against 125,021 tons; Glass Houghton, 76,519 tons, against 100,904 tons; Manvers Main, 77,138 tons, against 90,876 tons; and Grimesthorpe and Frickley, 72,163 tons, against 90,470 tons. Receipts, however, were not wholly on the down grade. Darfield Main, Elsecar, Hickleton, Monckton Main, Monk Bretton, Peckfield, and Yorkshire Main, all sent bigger tonnages, the most notable increase being that of the South Kirby, Featherstone, and Hemsworth collieries, which sent 105,176 tons, as compared with 59,412 tons in 1917.

Iron and Steel.—Labour unsettlement in the provincial iron and steel industries is reflected in the South Yorkshire trades, though perhaps in a minor degree. So far, carefully organised negotiation has prevented anything in the nature of actual eruption, and while conditions are by no means settled, there is no immediate likelihood of a break in the relations of employers and employed. It would be idle to pretend, however, that the general feeling of unsettlement is without effect on current conditions and prospects. Until smoother working is established, manufacturers and merchants naturally hesitate to commit themselves to obligations extending very far ahead, and as a general result business is being held up. Thus, though some departments are not working full time, orders are being turned away. Crucible furnaces are working short time, but in the departments for finished steel products the demand far exceeds the output. Rather more robust is the export trade, but in comparison to the number of inquiries the volume of business done is small. Railway steel departments have plenty of work on hand at the moment, though the effect of high prices of material and close competition is keenly felt. Business in billets is of a moderate character at the following rates:—Soft basic, 11*l.* 12*s.* 6*d.* hard basic, 10*l.* 15*s.* 6*d.*; Bessemer acid, 15*l.* 2*s.* 6*d.* Siemens' acid, 15*l.* 12*s.* 6*d.* The release of ore to tungsten makers has caused a marked deflation in high-speed steel prices. Best quality steel has declined from 4*s.* 5*d.* to 3*s.* 11*d.* per pound, and second quality 3*s.* 8*d.* to 3*s.* 4*d.* Makers of files and steel tools are working under pressure, but will be much better able to meet the big demands made upon their output when the task of adapting war

plant to civil needs is completed. New plant is being installed in forges and rolling mills to ensure production on the most efficient basis.

South Yorkshire Coal Trade.—Conditions are running rather more smoothly in the South Yorkshire coal trade, though the effect of recent interruptions in delivery has not been entirely effaced. Works still complain of the short tonnage at their disposal, and would readily take a larger share of the output if it were available. Only a moderate amount of overseas business is being done. Both gas fuels and slacks are in big demand, no surplus tonnage remaining for open market disposal. Prices all round are firm at the following rates:—Best branch hand-picked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Demand for Cleveland pig-iron continues heavy, and a fair amount of business is passing. Transactions, however, are still very largely restricted to sales to home customers to meet early requirements. The scarcity of foundry quality appears to be even more acute than it has been. Under the conditions prevailing it is quite impossible fully to satisfy home needs, and for the present, producers will not entertain neutral business, inquiry for which is very heavy, especially on behalf of Scandinavia and the Far East. Although every effort is made to distribute the iron available in an equitable manner, some foundries have been laid idle through shortage of supply. Difficulty is no longer experienced in securing export licences, and there is no scarcity of tonnage, so that the absence of foreign trade is entirely due to inability to obtain the class of iron needed for shipment abroad. It is almost impossible to buy iron for export just now, except for France, and shipments to that country are by no means large. It is unfortunate that there seems no prospect of any material increase of output of foundry pig-iron, at all events in the immediate future. Forge and mottled, and white iron, are very plentiful, and are being used as extensively as possible. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for export, No. 3 and the lower qualities are 145*s.*, and No. 1 is 150*s.*

Hematite Iron.—The situation as regards East Coast hematite iron shows further improvement. With supply sufficient to go round, trade is proceeding steadily, and so long as means of distribution can be arranged, all home needs are satisfied; whilst rather more iron is obtainable for shipment abroad, but the quantity available for such despatch is still only small, and licences are very difficult to secure. Nos. 1, 2 and 3 stand at 122*s.* 6*d.* for home use and 172*s.* 6*d.* for export.

Coke.—Coke is certainly less scarce, but the improved deliveries still leave much to be desired, and consumers are as insistent as ever in their pressure for larger supplies to the blast furnaces. Medium furnace quality is 33*s.* at the ovens, and low phosphorus sort 35*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—Labour troubles have had some disturbing influence on certain branches of the finished iron and steel industries, but manufacturers are full of orders, and output is heavy, particularly as regards railway material, and constructional steel. To home customers, common iron bars are 15*l.* 10*s.*; steel ship, bridge and tank plates, 14*l.*; steel ship angles, 13*l.* 12*s.* 6*d.*; steel boiler plates, 15*l.*; chequer plates, 15*l.* 10*s.*; steel joists, 13*l.* 12*s.* 6*d.*; heavy steel rails, 13*l.* 10*s.*; and billets and blooms, 11*l.* 2*s.* 6*d.* to 12*l.* 15*s.*

Ironworkers' Wages.—The accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England have certified the average net selling price of bars and angles for the two months ended December 31 last at 15*l.* 10*s.* 9·11*d.* per ton, as compared with 15*l.* 6*s.* 3·69*d.* per ton for the previous two months. This carries an advance of 3*d.* per ton on puddling, and 2½ per cent. on all other forge and mill wages, but in accordance with the Ministry of Munitions Lines of Settlement of January 3, 1918, and February 20, 1918, the advances merge into the 12½ per cent. bonus, and the 7½ per cent. bonus granted under those settlements. The accountants make a note to the effect that in accordance with instructions contained in a letter dated April 16, 1918, from the Ministry of Munitions, the average realised price for the two months ended December 31 should be increased in respect of subsidies granted to pig-iron makers, by the sum of 20*s.* per ton on sales for home consumption. After making this adjustment, the ascertainment is increased to 16*l.* 10*s.* 0·63*d.* per ton.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The demand for large coal continues active, and shipments are being pushed forward with as great a despatch as possible, but the docks, as pointed out before in these notes, are unable to cope with the pace at which tonnage is arriving, and there now prevails a state of real congestion. The frost this week interferes somewhat with the working of the tips owing to the hydraulic appliances being affected, but the number of hoists temporarily incapacitated have been comparatively few. The damage done, however, though limited, has accentuated the deficiencies in the facilities for the shipment of coal and the number of vessels awaiting turns has consequently been augmented. Best bunker smalls are firm, with washed smalls also in request, but the lower grade descriptions are weak, while throughs show no improvement. The decision of the local Coal and Coke Supplies Committee to allow the supply of coal for household consumption has had very little effect on the market, as the quantities of coal consumed for domestic purposes are small relative to the output, but the concession is a public convenience and much appreciated. Pitwood supplies are still short, and the conditions governing exports from Spain and Portugal are practically prohibitive. There is no alteration in the coke market, supplies continuing to be retained as far as possible for home consumption.

Newport.—The demand for Monmouthshire steam coals, particularly Black Veins and other descriptions, is very active, while inquiries for inland consumption are also numerous and pressing. Transport facilities are improving slightly, but they are still unsatisfactory, and are operating as an impediment on both production and distribution. Washed coals are in fairly good demand, but other qualities of smalls are weak. Shipments are very active, and the Alexandra Docks Company have just brought into use one of the three new hoists, for which contracts were placed as far back as 1914, and structural operations have also been commenced for the erection of another tip, while it is expected that a third new tip will be taken in hand early in April.

Coals for Neutrals.—It will be recalled that a practically free market was restored to neutrals within the limitations of the Coal Controller's directions as contained in the circular issued on January 17. Collieries are now informed that the District Coal and Coke Supplies Committee have discussed with the Coal Controller the question of allocation to colliery companies of coal for neutral destinations, and that it has now been definitely decided that no such allocations are to be made. All South Wales colliery companies are urged, however, to obtain the highest price for the coal supplied to neutrals. The minimum prices scheduled by the Controller have been occasionally exceeded since the allocations were suspended, and, in so far as the large coal market is concerned, the conditions are favourable to the securing of enhanced figures, but business with the local markets is still largely confined to allied destinations, and there would appear to be very little prospect for some time to come of any substantial increase in the quantity of coal available from the South Wales coalfield for shipments to neutrals. Though in individual cases prices appreciably in excess of the scheduled minimum prices are being quoted for neutral buyers, it cannot be said that any market price has yet been established for this business.

The Miners' New Demands.—Statistics have been compiled which show that the average underground wage (including the lowest paid labourers and boys) in the South Wales coalfield in 1914 was at the rate of about 93*l.* per annum. To day, however, this average has mounted up to between 170*l.* and 180*l.* per annum. Moreover, while in 1914 the average cost of labour and stores per ton of large coal was about 15*s.* 3*d.*, to-day it is over 35*s.* per ton. It will thus be seen that if the new demands are to be conceded, the price of coal will reach a figure which will constitute a menace to the future industrial well-being of the country.

Allegations of Unsafe Workings.—It will be recalled that the workmen at the Llanhilleth Collieries, Monmouthshire, and subsequently at other collieries, have been refusing to go down the pits on account of alleged accumulations of gas. An exhaustive inquiry was instituted into the position at the Llanhilleth Colliery, with the result that Sir Richard Redmayne, the Chief Inspector of Mines, has repudiated these allegations, and has given it as his opinion that there was no justification for the allegation that gas had accumulated to such an extent as to render the workings dangerous. The miners, however, are dissatisfied with the findings of the Chief Inspector, and representations are being made to the Miners' Federation of Great Britain to take action in the matter.

Colliery Clerks and the Miners.—Considerable discussion has recently taken place regarding colliery clerks being allowed to become members of the Miners' Federation. Those in the employ of the Hills Plymouth Company, in the Merthyr district, made an application for membership, and one of them actually joined the federation. The owners, however, take exception to this procedure on the ground that these clerks have access to confidential information. Ultimately the matter was referred to Sir Guy Calthrop, the Coal Controller, who has now replied that he cannot support the claim made. The Miners' Federation, however, are endeavouring to secure the membership of all colliery clerks, and a conference is now being suggested with the view of furthering this proposal.

Miners' Aggressive Policy.—The Naval Lodge of the South Wales Miners' Federation have refused to permit the senior haulage engineman, on being promoted to the position of winding engineman, to become a member of the Winding Enginemen's Association. A meeting of the latter was held at Cardiff on Saturday to consider the position thus created, and decided upon the adoption of protective policy as against the federation, and it was resolved that in future under no circumstances could they advise their members to teach haulage engine men, and that no person be permitted to work the engines unless he was prepared to join the enginemen's society. It was further pointed out that it was unfair, in view of the fact that the Winding Enginemen's Association had been in existence for twenty-five years, that the miners should now attempt to destroy that organisation.

NOTICES OF MEETINGS.

THE INSTITUTION OF SANITARY ENGINEERS.—Monday, February 17, at Caxton Hall, Caxton-street, Westminster, S.W., when the Presidential Address will be given. The retiring president, Mr. G. Bertram Kershaw, will take the chair at 7.30 p.m.

THE ROYAL SOCIETY OF ARTS.—Monday, February 17, at 4.30 p.m., Cantor Lecture: "The Scientific Problems of Electric Wave Telegraphy," by Dr. J. A. Fleming, F.R.S., Professor of Electrical Engineering, University College, London (Lecture II). Wednesday, February 19, at 4.30 p.m., Ordinary Meeting: "The Use of Electricity in Agriculture in Germany," by Mr. John Francis Crowley, D.Sc., B.A., M.I.E.E. Sir John F. C. Snell, M.Inst.C.E., M.I.E.E., will preside.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, February 18, at 5.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "The Financing of Oilfields," by Mr. Montagu Summers. The chair will be taken by the president, Mr. Charles Greenway.

THE JUNIOR INSTITUTION OF ENGINEERS: NORTH-EASTERN SECTION.—Tuesday, February 18, at the Mining Institute, Newcastle-on-Tyne, paper on "High-Tension Transmission Lines, Overhead and Underground," by Mr. G. S. Lisle.

THE ROYAL AERONAUTICAL SOCIETY.—Wednesday, February 19, in the Central Hall, Westminster, a Lecture will be given by Mr. Claude Graham White, entitled "Civil Aerial Transport—Is it Practicable; is it Safe, and is it Profitable?" The chair will be taken at 8 p.m. by Major-General the Right Hon. J. E. B. Seely, C.B., C.M.G., D.S.O., M.P., Under-Secretary of State for the Air Ministry.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, February 19, at 5 p.m., at 70, Victoria-street, Westminster. Papers to be read: (1) "The Lunar Tide in the Earth's Atmosphere," by Mr. S. Chapman, M.A., D.Sc.; (2) "The Gunfire on the Continent during 1918: Its Audibility at Chignal St. James, near Chelmsford," by Mr. Miller Christy, F.L.S.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, February 19, at 8 p.m., at the Royal Institution, Colquitt-street, when a paper will be read by Mr. J. Purves, entitled "Boiler Mountings."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, February 20, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Lecture on "Dielectrics in Electric Fields," by Mr. G. L. Addenbrooke, Member.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON.—Thursday, February 20, at 7.15 p.m., at the Caxton Hall, paper by Mr. T. Thompson, Darlington, on "Locomotive Building Practice."

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, February 21, at 5.30 p.m., a discourse will be delivered by Mr. A. T. Hare, M.A. The subject will be "Clock Escapements." Afternoon Lectures at 3 p.m.: Tuesday, February 18, Captain G. P. Thomson, M.A., on "The Development of Aeroplanes in the Great War" (Lecture I); Thursday, February 20, Professor H. Maxwell Lefroy, M.A., F.E.S., F.Z.S., on "Insect Enemies of our Food Supplies" (Lecture I); Saturday, February 22, The Hon. J. W. Fortescue, C.V.O., LL.D., on "The Empire's Share in England's Wars—Western Empire" (Lecture I).

POTASH IN CEMENT MILL DUST.—In the oil-fired plant of the Riverside Portland Cement Company, where cement dust was first collected for its potash content, the greater part of the potash is recovered in the water-soluble form; the fractions of potash that can only be dissolved in acid or which are insoluble even in acid, are relatively small. It was later observed, however, in coal-fired plants that the bulk of the potash in the dust could only be dissolved in acids if at all, and such potash dust would, of course, have an inferior value as fertiliser. To account for this observation, first made by R. C. Haff at the Security Cement and Lime Company, it was suggested that the potash volatilised as such recombined in the kiln with the siliceous ash particles of the coal fuel, or that the acid-soluble potash was directly due to the coal ashes and to dust particles of the raw mixture mechanically carried over. Investigating this problem, Albert R. Merz and W. H. Ross, of the Bureau of Soils, Washington (*Journal of Industrial and Engineering Chemistry*, January, 1919, pages 39 to 45), come to the conclusion that the water-soluble potash owes its source (*a*) to the volatilisation of potash during the burning of the cement; (*b*) to the decomposition of potash silicates in the raw mix mechanically carried over; and (*c*) to the ash of the coal, the potash of which is liberated by the action of lime. The sources of the acid-soluble potash are on the other hand: (*a*) Recombination of some volatilised potash with the fuel-ash; (*b*) recombination of some potash with the siliceous material in the mix (this only to a much smaller extent); (*c*) a partial decomposition of the silicates of the raw mix and of the ash mechanically carried over. The portion of the potash which has undergone recombination is of the nature of a potash slag or glass; when little potash is volatilised, particularly in the presence of carbon, there will be recombination, which might be reduced by keeping an oxidising rather than a reducing atmosphere in the kiln, and further by introducing lime or common salt into the dust at the hottest part of the kiln. The tendency to recombination is low when much potash is volatilised, and large when little potash is volatilised, and shows this most with poor recoveries.

4-TON "TOPLIS" LUFFING CRANES AT A SHIPYARD.

CONSTRUCTED BY MESSRS. STOTHERT AND PITT, LIMITED, ENGINEERS, BATH.

(*For Description, see Page 208.*)

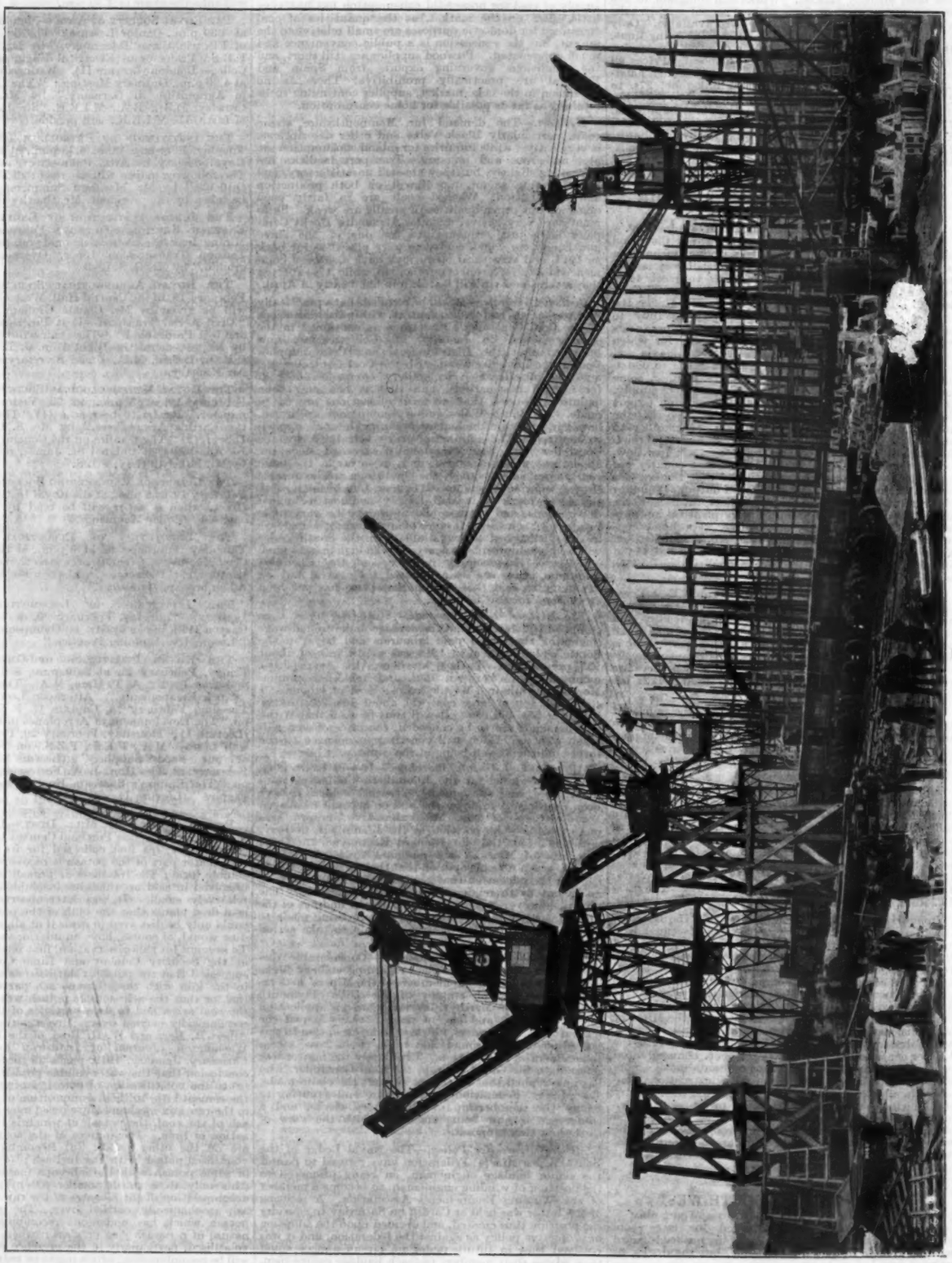


Fig. 4.

AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Turner and Henderson, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
CANADA. Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers. Montreal: Sells, Limited, 302, Shaughnessy Building, McGill-street.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE. Paris: Boyveau and Chevillet, 22, Rue de la Banque. For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink and Co. Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan, and any post-office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son,
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Cape Town: Wm. Dawson and Sons, 31, Long-street.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S. Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£2 9 0
For Canada—	
Thin paper copies	£2 5 0
Thick ,, ,,	£2 9 6
For all other places abroad—	
Thin paper copies	£2 9 6
Thick ,, ,,	£2 14 6

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—8663 and 8568 GERRARD.

CONTENTS.

	PAGE
Torsional Loads in the Fuselage of an Aeroplane (*Illus.*)	195
Economic Size of Concrete Ships (*Illus.*)	195
Templets, Jigs and Fixtures—No. XX. (*Illus.*)	197
The Employment Manager	199
Barnaby's Self-Discharging Grab (*Illus.*)	200
The Manufacture and Design of Toothed Gearing (*Illus.*)	202
The Double-Reduction Geared Turbine Steamer "Merida" (*Illus.*)	207
Four-Ton Topsle Lifting Crane for Shipyards (*Illus.*)	208
Notes from the North	210
Notes from South Yorkshire	210
Notes from Cleveland and the Northern Counties	211
Notes from the South-West	211
Notices of Meetings	211
New Industries for Engineers	213
Electric Arcs	214
Light Emission from Gases	215
Projection of Vessels from Moored Mines (*Illus.*)	216
A British Agricultural Engineering Shop in War Time (*Illus.*)	217
Industrial Notes	218
Procedure for Ordering Steel Materials	219
International Labour Legislation	219
Policy of Work	219
The Late Professor G. Carey Foster, F.R.S., J.P.	219
The Railway Problem	220
"Coal saving by the Scientific Control of Steam Boiler Plant"	220
Capital and Labour	220
The Variation of Measuring Instruments (*Illus.*)	220
Sound Fields and Sound Antennæ	224
ENGINEERING Patent Record	227

With a Two-Page Plate of the DOUBLE-REDUCTION GEARED TURBINE MACHINERY FOR THE S.S. "MERIDA."

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 211

ENGINEERING.

FRIDAY, FEBRUARY 14, 1919.

NEW INDUSTRIES FOR ENGINEERS.

ADHERENTS of the materialistic school of economics have been wont to wax eloquent on the theme that each nation should confine its manufacturing activities to the production of such commodities as are specially suited to its natural and industrial conditions. All other commodities should, it is claimed, be imported from countries where circumstances are more favourable to these particular manufactures and products. The proposition is, of course, eminently plausible. No one, for example, would propose to supply our demand for oranges by developing here the culture of orange trees in hothouses, nor is our proposed forestry authority likely to attempt to raise in the wilds of Wales and the highlands of Scotland crops of mahogany or teak. As a reliable guide to an economic policy, however, the axiom above quoted suffers under the disability that in most cases it is far from easy to determine off hand whether a particular commodity is well adapted for production in a given country or industrial area. In all the easy cases plain commonsense is sufficient to arrive at correct conclusions as to the prospects of a proposed industry, whilst in the difficult cases the maxim in question is, as experience has shown, likely to lead to wholly erroneous views. A reliance on it would, for example, have prevented the establishment of the large and prosperous engineering undertakings of Switzerland, a country practically devoid of coal and iron. Water power was no doubt available there, but this fact played no part in the founding of the great firms of manufacturing engineers, whose products, in spite of Switzerland's lack of a seaboard, have entered into effective competition with our own all the world over.

Politicians of the older school who drew their inspiration from this formula, and those survivors of it who have learnt nothing and forgotten nothing during the past strenuous years, had, and have, one simple formula for determining whether or no a particular product is better adapted for manufacture abroad than at home. This criterion is the price at date in the British market. Our ancestors, on the other hand, thought that the establishment of an industry in this country might be cheaply purchased, even at the cost of a temporarily enhanced price to the general consumer. Thus in the reign of Charles I a monopoly for the manufacture of alum was granted to an enterprising Yorkshireman, with the ultimate result that the home price fell greatly below that of the imported article.

The above observations have a very direct bearing on the report of the Engineering Trades (New Industries) Committee, of which we published an abstract on January 24th last (p. 122 *ante*). In this document many manufactures are enumerated, our demand for which has been supplied by importation, though they could equally well be made in this country. In many cases the condition of affairs in question has been brought about because foreign countries have deemed it their duty to foster native industries, whilst for many decades past Parliament here has been actuated by very different motives. The committee, for example, call attention to the disastrous effect of Mr. Chamberlain's Acts of the early 'eighties on the development of the heavy electrical engineering trades in this country. These Acts constitute a striking instance of how blatantly even a clever man may blunder when he elects to be guided by logical formulas instead of by evidential facts. One of Mr. Chamberlain's aims was to protect the consumer from extortion. It certainly cannot be denied that this object was for many years very completely attained, since if a consumer is not permitted to come into existence it follows *a fortiori* that his victimisation is impossible. His second object, the promotion of municipal enterprise, had equally unfortunate results. The field of heavy electrical engineering in which at that time we led the world was, the committee state, "hampered by stupid repressive legislation." Development was accordingly slow here and rapid abroad, and when finally, a move was made, the municipalities deliberately gave every preference to foreign firms, on the ground that they must not risk the ratepayers' money in giving orders to make s without large experience in the kind of work required. This contention was indeed carried to extraordinary lengths. We remember a case in which a British firm, which had a singularly favourable record in steam turbine building, found its tender rejected in favour of a Continental machine because the largest unit the firm in question had then constructed was rated at 2,500 kw., whilst an output of 3,000 kw. was demanded by the specifications. The committee note that this practice still persists, and that both Government and municipal authorities refuse to accept British tenders for high-tension switch gear on the ground that our manufacturers have not had as much experience with this class of goods as certain foreign firms. If, as some sections of labour demand, all great undertakings are to be municipalised or nationalised, the outlook for progressive manufacturing firms in this country would appear far from seductive.

There are, of course, other varieties of engineering products of which the quantity imported was far in excess of the home production. This condition has certainly not arisen from any lack of engineering ability on our part. The nation which during the past quarter of a century has devised the steam urbine and the pneumatic tyre has an indefeasible defence against a charge of slow-wittedness in matters mechanical, and it is not without interest to note that in spite of the legislative drawbacks to which reference has been made above, the three men mainly responsible for modern methods of electrical distribution are all British subjects, viz., Mr. C. E. L. Brown,* Mr. S. Z. de Ferranti and Sir Charles Parsons.

Moreover, the experience of the past 4½ years would of itself be sufficient to demonstrate that a lack of mechanical and scientific ability was not a factor in our failure to develop certain manufactures for which the national conditions here appeared in every way suitable. During the war we have made, at short notice, and in large quantities a vast variety of goods previously imported, many of which, moreover, were regarded by their foreign producers as being dependent on trade secrets known only to themselves, and not to be discovered save at the cost of years, rather than months, of work. The enormous outputs realised in our various munition factories run by unskilled labour, often female, show further that organising ability has not been lacking any more than mechanical aptitude or scientific knowledge. The war has demonstrated that men with these qualifications were not wanting, but the enterprise to employ them. In part, this has no doubt been due to the narrowly-specialised character of our curriculum for secondary education, but the jealousy with which Parliament has regarded industrial enterprise in the past has perhaps counted for even more. The American plan of fostering native industries has given the world the cheapest motor car and the cheapest internal-combustion engines yet made. Here, any proposal to make a new railway, or to provide cheap power, has for years past had to meet the determined opposition of men who would apparently prefer that an industry should not exist, if its existence depended on its being profitable.

Our governing bodies have also hampered industries in other ways. The maxim of Tiberius that taxpayers should be sheared and not flayed has been consistently disregarded so far as manufacturers are concerned, both by the Treasury and the rating authorities. It is notorious, for example, that

* Mr. Brown's work, of course, was carried out in Switzerland.

official allowances for obsolescence of plant have been most inadequate. The practice of Somerset House in this regard has been a serious handicap to the introduction of special machine tools. Could these be written off in, say, five years, the risks attaching to standardisation would be materially diminished, as there would be less likelihood of a firm finding at the end of such a period that it was lumbered up with tools valued highly on its books, but owing to changes of methods or design of little worth intrinsically. A striking instance of how the value of a tool may be affected by a sudden alteration in conditions, was afforded at a recent sale of the plant at one of the National workshops in the Birmingham district. Here a shell-banding machine which cost 420*l.* fetched but 10*l.*, being under the altered conditions valuable only as scrap.

The committee, in the report under review, observe that many engineering firms are threatened with serious financial troubles unless prompt steps are taken by the Government to finance payments legally due to Treasury on account of munitions levy and excess profits duties. Under pressure many firms have spent vast sums in extensions, exhausting in this way not merely their working capital but the excess profits earned but not yet paid into the Treasury. No doubt the excess profits duty has in many cases borne somewhat unfairly, though in principle there was much to be said for the view that those in a position to supply the abnormal demand of the nation for certain classes of goods, should not be permitted to exploit the situation. So far as the capitalist was concerned, this end was secured in a rough and ready fashion by the tax in question, but no statesman has been bold enough to propose a similar tax on the excess profits of the workmen, which in the aggregate, of course, far exceeded those of the shareholders.

The committee express the opinion that the tax should now be abandoned. If maintained it will certainly constitute a premium on bad or indifferent management of industrial undertakings. The workman who, when called upon to pay income-tax for the first time, avowed that in future he would keep his earnings below the limit for exemption, will undoubtedly have imitators amongst works proprietors, if the excess profits tax be maintained.

A reform which would go far to meet the situation, both as regards excess profits and allowances for the obsolescence of machinery, would be to levy income-tax on dividends only. Receipts ploughed back into the business for extensions or for improvements of plant would thus come up for taxation only when they began in their turn to yield a dividend. The stimulus to improvement thus afforded could in the ultimate bring more into the Treasury than would be received by a continuance in the short-sighted policy of the past. The task of assessors would be simplified, though this consideration will hardly commend the plan to the Treasury in view of the circumstance that the natural corollary would be a reduction in the staff—a measure never popular in any department of the Civil Service.

The committee urge that Government departments should specify standard goods wherever possible. As matters stand, not only engineers in official positions, but many consultants insist on departures from standard models, which are changes without being improvements. Official specifications, moreover, have generally been prepared without any regard to questions of manufacturing convenience. There is a strong suspicion that this practice has been deliberately encouraged by certain firms on the War Office and Admiralty lists. Having equipped themselves with plant specially designed to cope with difficulties attaching to these official fads, these firms were by no means anxious for simplifications which would have had the effect of augmenting the number of their competitors. Such firms will hardly welcome the recommendation of the committee that before final issue all Government specifications and designs should be submitted to a committee of experts in workshop processes.

ELECTRIC ARCS.

Electric-arc problems take us back to the infancy of electric illumination. One might think that the studies of Mrs. Ayrton, W. Duddell and others in this country, and the not less distinguished researches conducted elsewhere, had fairly settled those problems. The two lectures on "The Study of Electric Arcs and their Applications," which Professor J. C. MacGregor-Morris, M.I.E.E., of the East London College, delivered on the first two Tuesdays of this month, at the Royal Institution, however, do not prove only that a great deal of useful work on arcs has been done in the last few years, but also that a great deal remains to be done. Davey, Professor Morris pointed out, saw the first arc between two carbon electrodes in 1801; the expression "an arch of light," 4 in. long, was used by Davey in describing his experiments with a powerful battery in 1808—others had been working on the same lines meanwhile; when the term arc was substituted for arch, Professor Morris could not say. Sending strong discharges through an induction apparatus with electrodes of brass or carbon, he showed that the spark colour depended on the atmosphere, the arc colour on the material of the electrodes. When the colours were referred to a colour diagram—a triangle, the corners of which were marked red, green, blue respectively—the Hefner (amyl acetate) lamp appeared the least blue, whilst the carbon filament, the Welsbach burner, metal filament, afternoon sun and mercury arc were approaching the blue corner more and more. Thrown on a screen the arc appeared as a bluish vapour column surrounded by a greenish halo, which was formed by the products of combustion.

As regards volt-ampere characteristics of arcs, Professor Morris gave a table of Mrs. Ayrton's formula for the carbon arc in air and of the formulæ of W. Grotrian for metal arcs in various gases, the latter not in Grotrian's own form, however, but as modified by Morris. Mrs. Ayrton's formula was: $e = 38{\cdot}88 + 2{\cdot}074\ l^1 + 0{\cdot}54\ l^1/\mathrm{I} + 11{\cdot}66/\mathrm{I}$ (e being the electromotive force, l and l^1 the length and corrected length, and I the current); Grotrian-Morris formulæ for iron in air or nitrogen: $e = 62 + 11{\cdot}4\ l + 32{\cdot}6\ l/\mathrm{I}$, and in hydrogen $e = 290\ l + 222\ l/\mathrm{I} + 180/\mathrm{I}$. Grotrian himself (*Annalen der Physik*, 47, pages 141 to 196, 1915), we may mention, wrote his formulæ in a different way, for the arc in hydrogen, *e.g.*, $180 + 222\ l + 290$ I. Grotrian accepted Mrs. Ayrton's type of formula for all cases in which a sharply-defined band can be seen in the centre of the arc; he found that band missing, *e.g.*, in arcs burning in water vapour at low current intensity. What one would like to see at a glance from such formulæ, to make them directly comparable if possible, is the absolute term, independent of the arc length; in the formula of Professor Morris the absolute term for the hydrogen arc is missing; the term $290\ l$ indicates, however, that the arc consumes much power in hydrogen, six times as much in fact, as in air under similar conditions; the hydrogen arc yields also a much higher temperature, hence Grotrian had to use iron rods, 3 cm. in thickness, to prevent their melting. He experimented with arcs up to 50 cm. in length, on the lines of the long arcs (metres in length) which Schönherr introduced in 1909 for the oxidation of nitrogen, sending an ascending spiral current of air (or other gas) up a tube to keep the arc steady. Grotrian, as Professor Morris mentioned, also determined the anode and kathode drop of potential and the potential gradient along the arcs which he found uniform in the arc proper. In flame arcs the main drop, about 33 per cent., occurred at the anode; there was a drop of about 25 per cent. at the kathode, and the rest down the column. Taking the drop with carbon electrodes (Mrs. Ayrton's formula) at 38·88 volts, the least drops were observed with electrodes of silver (14·2) and iron (15·7), copper giving 21·34 volts, platinum 24·3 volts. According to Grotrian the characteristic of the arc was little influenced by the nature of the electrodes, but strongly by the nature of the gas (N, O, air, H, water vapour, CO_2).

The oscillograph, Professor Morris proceeded, afforded much more convenient means of studying arc characteristics than the early direct volt and ampere measurements, with which one might have to wait a long time for steady conditions; hissing arcs did not give concordant results. One of his experiments was a novel way of exemplifying that parallel currents attract one another: Two wire loops were suspended from the same carbon; the lower ends of the loops drifted together when the current was turned on. Professor Morris also demonstrated the magnetic blowpipe effects. The arc was thrown on the screen and a strong electro-magnetic field was excited; not only the bluish arc, but also the greenish aureole were blown to the right or left, and even the spherules of fused salts and carbon falling from the positive pole upon the negative were hurled away as if by a strong blast. When the arc was alternating (and humming, therefore), the electromagnet seemed to divide the arc horizontally, and to deflect it both ways. The experiments, Professor Morris remarked, required further elucidation; one did not see why the combustion gas in the green aureole should be deflected; he did not speak of the fused spherules. That the arc adhered to the negative pole whilst it could easily be detached from the positive pole, he continued, had been shown by Steinmetz, who approached a third positive or negative electrode to the arc and thus succeeded in transferring the positive end of the arc to the third electrode, but failed to accomplish that with the negative electrode. Professor Morris himself and Captain Mallett have recently investigated this problem with the aid of a T-electrode of carbon. When the upper negative carbon was a rod, the lower positive a T, the arc, deflected (by the electromagnetic field) to the right or left, curved, but remained attached to the bar of the T, increasing in length when further deflected. The arc thus behaved like a piece of rubber; it was stretched by the electromagnetic force deflecting it, yet it had a certain elasticity or tension in it which tended to shorten and to pull it back again. Experimenting with arc currents of 6 amperes at 240 volts, they had found that this force was of the order of a few dynes, there being a push on the anode and about three times that push on the kathode; the figures exhibited showed forces up to 13·7 dynes, but these forces were greater in hissing arcs, the lecturer added. Something of this kind was noticed in the mercury pool of a mercury-arc lamp; there was a depression in the centre, and the unsteady arc wandered off to the edge. In making these determinations Professor Morris attached the lower electrode of the enclosed arc to a balance beam. He mentioned also similar experiments by M. La Rosa, and that Professor Dewar had years ago observed that there was, within the arc, an increased gas pressure of about 1 mm. of water; Dewar had not followed that point up, however.

When experiments were made with alternating arcs, and a stroboscopic slit disc was turned in front of the arc, at a rate such that two consecutive holes appeared $\frac{1}{85}$ second apart with currents of 83 periods, the crests or hollows of the alternating current waves could be observed, Professor Morris demonstrated, and it could then be seen that the light started from the positive pole and came back to it from the negative. As the speed of the disc was varied, the one or the other pole looked bright. When the electromagnet or blow pipe was turned on, the blue arc was seen on the right, *e.g.*, the green halo further out on the right, while the ghost of the green halo of the last deflection was still noticeable on the left. That the arc itself was slowly rotating under certain conditions had first been observed by Mr. Trotter. In that case the negative end of the arc held on, the positive rotating, and the rotation was only distinct when the arc was emitting a musical sound. Part of this phenomenon at any rate was demonstrated by Professor Morris by placing a loud-speaking telephone in circuit with the arc; the carbons were drawn too far apart first to hiss, and that gave a roar in the telephone; when the arc was shortened, a musical sound was momentarily heard; during that period, Professor Morris explained, the rotation could be observed. That the arc column was not continuous, but stratified horizontally and broken up into patches of luminosity was explained with the aid of instantaneous photographs (exposures of $\frac{1}{300}$ second) due to W. Frey and to M. La Rosa.

Passing to some modern apparatus, Professor Morris first referred to the mercury arc converter. It consisted of a glass vessel; the lower portion was a mercury pool; two lateral extensions in the middle contained two carbon electrodes, C_1 C_2,

axially opposite one another; the upper tubular portion served as condenser for the mercury. C_1 and C_2 were connected with the terminals of an alternating current coil, the middle point of which was joined to a continuous current source; a small mercury nest close to the pool was separately joined to the one alternating terminal through a resistance. Arcs stretched over to the pool, the kathode, alternatively from C_1 or from C_2, the small nest serving as starting device. The photograph displayed exemplified this alternating arc play, and showed also that the two arcs may overlap; the converter would stop acting, the lecturer remarked, if the kathode were cooled. The second apparatus demonstrated was the pointolite lamp, which we have described; Professor Morris mainly referred to it in order to show the importance of the negative electrode. There was a little bead or ball of tungsten, 0·1 in diameter, mounted on a bimetallic arm (which bent when warm); near the ball were fixed a wire coil and rod covered with an oxide which, when heated by the current, ionised the inert gas in the bulb sufficiently to start the arc between the bead, the kathode, and the rod. For every powerful lamp (over 100 candles) there was further mounted in the lamp a rhombic disc of tungsten; when the current was started as just described and the bead was glowing, the current was switched over so as to make the bead the anode and the disc the new kathode; the disc then began to glow. Suspending one of the lamps (without disc) downwards, Professor Morris showed that with increasing current the tungsten bead could almost be seen to fuse.

In his third application Professor Morris referred to the experiments recently conducted by the late Mr. J. F. Forrest and himself on the use of the arc for light standardisation. They had first tried to surround a positive carbon rod by a negative tube; that device might have answered if they had reversed their polarity so that the negative end of the arc would be able to adhere to the central rod. Then they had placed the tube in front of the rod, but the tube had become filled with fumes. They had also inclined two rods to one another, and turned the one about its longitudinal axis. They had finally mounted three carbons in the same horizontal plane, so as to form a Y, the stem being positive, the two arms negative. The device was mounted in a closed iron case, and an image of the positive crater (seen endways) was thrown on a screen in front of the box, being produced by a small lens; a pin hole and a mirror further showed the plan of the carbons on the screen so that the experimenter knew how his carbons were adjusted. The rotation of the arc could be seen by watching the disc, and photographs of it disclosed want of homogeneity in the carbons. For photometric measurements the light of the crater passed through a stop (a hole in a brass plate) out of the box and on to a photometer; the area of that hole, about a square millimetre, had, of course, to be determined very exactly, and there might be trouble with diffraction. Otherwise the arrangement was very simple; current measurements were not required; the experimenter merely adjusted his arc until all hissing ceased. The figures shown by Professor Morris were certainly concordant, and from these it would follow that the positive crater has a brilliancy of 173 candle-power per square millimetre. There is thus hope that the electric arc may be utilised for standardising. Other estimates gave the intrinsic brilliancy of the carbon crater as 111,000 candles per square inch (which would agree with 173 candles per square millimetre), that of melting tungsten as 46,500 candle, and the following other candle powers: carbon filament, 381 to 420; Nernst lamp, 2,150; tungsten filaments, 1,000; half-watt lamp, 5,000; tungsten arc, 12,900. Estimates of the brilliancy of the novel types of searchlights were not yet available, the lecturer said.

We should like to add one remark to this brief account of Professor MacGregor-Morris's lectures. In demonstrating the deflection of the arc by the magnetic field, he did not draw attention to the fact that the molten spherules of carbon and salt impurities in the carbon were also hurled away, almost in horizontal paths sometimes; and when he said that the phenomena required further elucidation, he merely referred to the halo of gases. It is surprising that the electric blowpipe, which has been used for a good many years, is still so obscure a problem with respect to the arc. The arc itself consists probably of carbon ions, the vapours in the halo—which is sometimes absent, by the way, and need not always consist of combustion products—may be ionised, and that might also apply to the salts in the fused beads dropping from the positive electrode. Yet the force with which the spherules seem to be hurled away is surprising. Thermoionic currents have been much discussed of late; one can only wonder that the electric arc has not been particularly studied from that point of view. Grotrian attempted to explain his observations of arcs burning in various gases on the ground of ionisation by collisions; perhaps he was not acquainted with the work on thermoionic emission which seems to afford an easier explanation.

LIGHT EMISSION FROM GASES.

WHILE ordinary glow lamps are submitted to high-tension high-frequency discharges for the purpose of testing the vacua, nitrogen-filled half-watt lamps are examined by similar methods with the object of testing the purity of the gas charge. In Tesla-fields the internal wall of a bulb charged with nitrogen or with a mixture of nitrogen and argon displays a bluish phosphorescence which vanishes in the presence of traces of oxygen, hydrogen and carbon monoxide, and the colour of the electric discharge is also sensitive to the presence of impurities. Investigating in this connection the spectra of pure gases and of gas mixtures in discharge bulbs of special type, Dr. L. Hamburger made, in the glow lamp works of Messrs. Philips, of Eindhoven, Netherlands, use of a photographic method for determining the intensities of the lines under varying conditions of current density, gas pressure, &c. He works with continuous currents of relatively high density, mostly at pressures of about 1 mm. of mercury, and with apparatus of quartz or uviol glass of such a construction that he can study the phenomena both with the gases at rest and with the gases kept in continuous circulation at steady gas pressure by the aid of a pump. His account (*Zeitschrift für Wissenschaftliche Photographie und Photophysik*, August, 1918, pages 1 to 44) does not describe the apparatus in detail and pays more attention to theoretical features than to technical matters, referring to his dissertation published at Delft in 1917. But some of his observations are very interesting.

Passing strong currents, *e.g.*, of 292 milliamperes (7 amperes per square centimetre), through pure nitrogen, he observed that the gas pressure changed while the current was flowing; a gas pressure of originally 0·76 mm. of mercury decreased to 0.67 mm. on the kathode side and rose to 0·95 mm. on the anode side, returning to 0·76 mm. after breaking the circuit. Considering that the electrodes—a Wehnelt kathode with a speck of barium oxide or a tungsten spiral were used—became decidedly hot; the change is curious, and it looks as if the electrons carried gaseous molecules with them from the anode to the kathode. The effect was still observable at a gas pressure of 0·089 mm. Much weaker effects of this kind had been observed by Stark and others. In hydrogen there was less evidence of this pressure change; but attention is drawn to one feature, which is mostly overlooked, namely, that the hydrogen reduces the surface layer of the barium oxide and thus introduces water vapour into the pure gas. The different lines on the blue and red of the argon spectrum were differently influenced by changes in the discharge conditions; but traces of nitrogen did not further complicate these phenomena. The various helium lines likewise were affected to different degrees by the conditions of the discharge. In all the pure gases the intensity maximum of the light shifted more towards the violet with decreasing gas pressure. As regards gas mixtures Hamburger examined first mixtures of gases indifferent to one another. From mixtures of argon and nitrogen, nitrogen was absorbed by aluminium anodes. The efficiency of the neon light was much decreased by the presence of nitrogen; mixtures of neon and helium gave a whiter light than neon alone, but the energy consumption was higher. Argon containing mercury vapour showed the mercury spectrum strongly, but the intensity of the argon spectrum was little diminished. We will presently revert to this point. On the whole there is not much novelty in these observations of inert gas mixtures except that Hamburger gives photographic intensity measurements. With respect to nitrogen and hydrogen he finds direct evidence of an absorption band at wave-length 3360 Angström units which is absent from the spectra of nitrogen, of hydrogen and of mixtures of these two gases with other indifferent gases and which may therefore be ascribed to ammonia. Such a band had been observed by Eder in the ammonia-oxygen flame, but there was considerable doubt whether the so-called ammonia bands were not really due to some oxygen compound of nitrogen. Experimenting at high-current densities (12 amperes per square centimetre) in cooled capillary tubes Hamburger also obtained fairly satisfactory yields of synthetic ammonia by sending the current through mixtures of nitrogen and hydrogen; the yields were considerably better than any previously secured by similar methods, but hardly promising.

We come back to gas mixtures. Ramsay and Collie observed as early as 1896 that traces of argon are easily discovered by the spectroscope in helium, whilst the helium lines become, in mixtures of the two gases, only visible when helium is added in considerable percentages. That in many cases the spectrum of a gas mixture is not represented by the sum of the spectra of the constituents is fairly well established. It is a point that complicates solar and cosmic spectroscopy, and which is not sufficiently heeded in many researches and in technical spectrum analyses. Gehlhoff noticed in 1911 that mercury vapour at a partial pressure of 0.001 mm. suppresses the helium spectrum almost completely; the presence of alkali metals weakens the spectra of hydrogen and nitrogen very much. To account for such phenomena J. Stark suggested in 1904 that the lines of that gas will predominate which has the lowest ionisation potential. This argument seemed much strengthened when Franck and Hertz in 1913 made the signal discovery that, when the potential gradient is gradually raised to 4·9 volts in mercury vapour, an unknown single-line spectrum of λ 2536 A.U. suddenly bursts out. The mercury vapour, they argued, so far a non-conductor, then conducts the current and must hence be ionised, and the energy required for this ionisation exactly corresponds with the relation $Ve = h\nu$ of the quantum theory; where V indicated the potential in volts, e the charge, h Planck's constant, and ν the frequency. When an electron colliding with a gas molecule has not sufficient energy to ionise the molecule, the electron is reflected with a loss of energy, which is zero for the indifferent gases, but which increases with the electronic affinity of the gas; electronegative gases, like oxygen and chloride, have a strong affinity. Repeated collisions may go on without loss of energy; on the other hand, kinetic energy may be acquired on several free paths, and the energy may increase sufficiently to produce ionisation. Hamburger now argues that, when the gas pressure is reduced, the free paths of the molecules become longer, more energy can be acquired by collisions, and that would explain why his intensity maxima shifted, with diminished gas pressure, further into the ultra-violet. The phenomena would be somewhat similar as in F. Skaupy's sifting of gas mixtures by the continuous-current discharge; the more easily ionised gas, *e.g.*, neon (ionisation potential 3·5 volts) travels to the kathode, the less easily-ionised argon (12 volts) to the anode, and a separation of the two gases is thus effected.

There are, however, serious objections to all these arguments. Single-line spectra have been produced by McLennan and others by kathode bombardment of zinc, magnesium, &c. But on Bohr's theory—which is still practically the only one in the field—the whole spectrum, not merely a single line, should appear on ionisation, and one does not understand, moreover, why an ultra-violet mercury line which requires more energy for its excitation than the green and red lines, should first make its appearance.

It has been suggested that the first ionisation of Franck is the result of a photo-electric radiation, and not a real direct ionisation which requires the arc and in mercury 10·4 volts. But Millikan and Hebb, and later McLennan too, found that the mercury arc could be produced at 2·5 volts, and the sodium and potassium arcs at 1·4 volts and 0·5 volt; in the presence of potassium vapour, Hebb (Vancouver) observed the mercury spectrum already at 0·5 volt, in fact. The whole matter is thus highly controversial. It certainly seems strange, however, that in several of the researches mentioned the energy is all ascribed to the potential difference, though the investigators used Wehnelt kathodes or tungsten spirals, which are separately heated by battery currents.

PROTECTION OF VESSELS FROM MOORED MINES.

It has long been known in this country that our vessels could pass through the enemy minefields, but the secret of the device used for that purpose was exceedingly well kept. The accompanying illustration of the apparatus termed a "paravane," which has been used by the British Admiralty for the protection of all classes of vessels from moored mines, have now been passed for publication. For the invention of the paravane, we are indebted to Commander D. C. Burney, C.M.G., who brought it to the notice of the Admiralty in the early part of 1915. A special department was immediately formed at Portsmouth Dockyard to investigate the possibilities of Commander Burney's ideas, and the present type of apparatus, which has proved satisfactory under all working conditions, was the result.

The illustration, Fig. 1, gives an excellent view of the paravane stowed in the chocks of the rotary davit with all preparations for launching. It will be observed that it consists essentially of four parts, viz.: (1) A steel torpedo-shaped body providing the necessary buoyancy for supporting the device and its wire rope attachment to the vessel. (2) A conical tail with horizontal and vertical stabilising fins, and a rudder controlled by a secret mechanism to ensure the paravane running at a pre-determined depth. (3) A cambered steel plane connected to the body by means of a lightened plate tow frame, the dimensions and angle of incidence of the plane being determined by the speed of the towing vessel and the minimum outward thrust necessary to ensure the mine, when severed from the mooring rope, coming to the surface at a safe distance from the hull of the ship. (4) A specially-designed bracket of considerable strength carrying two removable cutter blades of high-quality steel, to withstand the severing, in rapid succession, of the 1 in. to 1¼ in. steel wire rope usually fitted between the mine and its sinker without suffering appreciable injury. This bracket is at ached to the tow frame on the opposite side to that of the plane. Connection to the ship is made by means of a steel wire rope specially constructed as regards form and material, as the preliminary tests showed that steel wire rope of the usual quality was very resistful in form and the material deteriorated rapidly under the excessive vibration experienced when the paravane is towed by a high-speed vessel.

The complete installation for a ship comprises two such units, each towed by a special cable as mentioned above from the bows of the ship, one cable on the port, and one on the starboard side, the whole forming, roughly, a huge V or wedge shape with the bow of the ship as apex. The combination of plane and torpedo body must be such that the outward thrust on the plane bears a definite ratio to the head resistance of the body, so that the form taken up by the wire admits of the mine-mooring rope readily sliding along the towing wire to the cutter blades in the head of the paravane. The apparatus is set to tow at a depth of about 3 ft. or 4 ft. below the level of the keel, and this depth is approximately maintained at all speeds of the vessel. The importance of constant depth running is readily seen as the safety of the ship is endangered by any appreciable upward movement of the towing wire attached to the paravane through the mines passing under and striking the ship. On the other hand, appreciable downward movement might cause the destruction of the paravane by its striking the bottom in shallow waters. This necessitated very careful design and great accuracy in manufacture, in both of which the results were such that the amplitude of oscillation of the paravane rarely exceeds 2 ft. to 3 ft. each side of the set depth.

All the difficulties of the problem of protecting vessels from mines were not surmounted with the successful design of the paravane. The form of the bows differed with the various types of ships, and considerable thought was required to arrive at some satisfactory arrangement for securing the inner end of the towing wire to the hull under all working conditions and in heavy seas. In vessels under construction the stem was modified, and a very efficient arrangement obtained with the minimum amount of additional work for the crew of the vessel. In completed vessels the type of fitting depended largely on the cut-away of the bow, and this, in addition to the danger of attachments collapsing under the heavy seas experienced in ocean-going vessels, created a further difficulty, in that standardisation and rapidity of manufacture, and therefore of installing ships with such fittings could be only partially attained at the expense of additional weight and cost. In spite of this, nearly 75 per cent. of the tonnage of Great Britain was protected with not a single instance in record of a vessel using the device suffering injury from the action of mines.

It must have caused the enemy considerable anxiety to find that our ships were passing uninjured through his carefully-laid death traps, and it was not long before steps were taken to circumvent the efficiency of the paravane, but it is satisfactory to know that our inventive genius has always kept well in advance. Indeed, at the present time one type of paravane can successfully sever the heaviest chain or wire rope mooring capable of being used to anchor any type of mine within practical limits.

THE "PARAVANE."

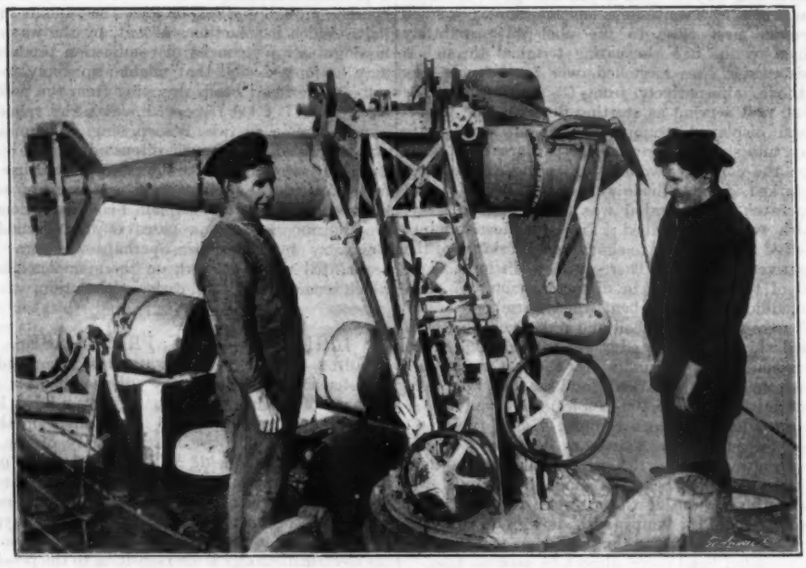


Fig. 1. Apparatus in Position on Board.

Fig. 2. The "Paravane" ready for Launching.

Krupps at Essen.—As a sign of the reconstruction movement in Germany, it is interesting to note an advertisement from the firm of Fried Krupp, enumerating their various establishments, the cast steel works at Essen, the Gruson works at Magdeburg, the Germania yard at Kiel, the Friedrich-Alfred iron works, Rheinhausen, the steel works Annen-Annen, and the Sayner iron works. The firm goes on to state that of the average steel production during the last five peace years 95·4 per cent. was used in the manufacture of peace material and only 4·6 per cent. for war material.

A BRITISH AGRICULTURAL ENGINEERING SHOP IN WAR TIME.

ENGINE ERECTING SHOP OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

THE illustration which we give above will be examined with interest as indicative of the great changes brought about in numbers of our important engineering works by the demands of the war. The view given is of a portion of the engine erecting shop of Messrs. Marshall, Sons and Co., Limited, of Gainsborough. In ordinary times the central area of this shop is for the greater part of its length devoted to the erection of agricultural engines, steam road rollers, and traction engines, the remainder of the length being occupied by the erection of stationary engines. The side bays and the galleries, which are very wide, are filled with machine tools of varied types, those in the galleries being chiefly for light work. As seen in the view referred to, the central area was during the war given up to naval gun mountings for torpedo-boat destroyers. Altogether 1,197 naval gun mountings were turned out by Messrs. Marshall, the record output for one month being 123 mountings.

The engine-erecting shop, however, was by no means the only portion of Messrs. Marshall's works affected by the war. Ordinarily the chief output of the firm consists of stationary and portable engines, internal-combustion engines, threshing machines, tea machinery, &c., and their works include a very extensive plant of wood-working machinery. During the war their work has been of a most varied character, and has included the following products: "Tanks" of the infantry supply type; aeroplanes, "Bristol Fighter" type; gun mountings for arming merchant ships; naval gun mountings for torpedo-boat destroyers; furnaces for manufacture of chemicals; distilling apparatus (stills and condensers) for making gases for military purposes; mixing machines for chemical manufacture; cordite presses and reeling gears; water-tank carts; limber general service wagons; limber R.E. wagons; limber wagons; Maltese carts; officers' mess carts; trench pumps; wheels for military carts and wagons; steel wheels for War Office lorries; steel tanks for storage of chemicals at filling factories; trucks for transport in filling factories; 5-ton trucks for traction haulage; ammunition boxes for howitzer, field gun and small-arm ammunition; steel shields for trench warfare; gun shields (various); trench mortar fittings; shells and shell components; fuses and fuse components; bombs and aerial torpedoes; battery cell boxes, &c.; steam engines, boilers and saw benches for war purposes. This list affords striking evidence of the aid which our engineering establishments have been able to afford to meet our military requirements during the war.

THE ROYAL SANITARY INSTITUTE.—The Royal Sanitary Institute have arranged a conference on "Post-War Developments Relating to Public Health," to be held on March 13, 14 and 15, at which the following subjects will be brought forward for discussion: "City Hygiene in Relation to Employment"; "Housing for City Clerks and Similar Workers"; "Public Health Aspect of Tuberculosis"; "Public Health Work and Propaganda"; "Welfare Work in Factories"; "Child Welfare Work."

DEALING IN SECOND-HAND RAILWAY MATERIALS.—The Minister of Munitions has suspended, as from the 7th inst., until further notice, the Railway Material (Second-Hand) Order, 1916, except in so far as relates to wagons of all types. Dealings in second-hand railway locomotives, rails, chairs, fishplates, fastenings, signal apparatus, sleepers and the like may now take place without a permit; but second-hand wagons of all types are still war material within the terms of Regulation 30A of the Defence of the Realm Regulations.

ASBESTOS PRODUCTION IN CANADA.—We read in *Engineering and Mining Journal*, New York, that the asbestos production of five of the largest shippers in Canada during 1917 was 3,708 tons of crude, 50,506 tons of fibre, and 3,550 tons of sand. In 1918, the same five companies produced 2,896 tons of crude, 74,109 tons of fibre and 14,038 tons of sand. The increase in tonnage in 1917 over 1916 was 3 per cent., and that of 1918 over 1917 approximately 2 per cent. The increase in value in 1917 over 1916 was 39 per cent., and the value was even greater in 1918. Stocks at the mines are depleted, and it is believed that higher prices will rule during 1919.

THE AMMONIA-COMBUSTION PROCESS.—The platinum gauze, which serves as catalyst in the combustion of ammonia to nitrogen oxide and nitric acid, is very easily poisoned by traces of many substances which might be considered harmless. It has been observed, for instance, that ammonia prepared from commercial cyanamide may give poor yields of nitrogen oxide NO, and that defect has been ascribed to the presence in the ammonia either of acetylene itself (which would be evolved if the cyanamide contained some calcium carbide, as it frequently does) or of the common impurities of acetylene. There are several possible impurities, the hydrides of silicon and phosphorus, sulphuretted hydrogen, carbon monoxide, nitrogen, oxygen, methane, &c. Of these, phosphine was under suspicion in the first instance. Experimenting in the United States Bureau of Mines with a very pure acetylene (specially purified) which they contaminated with impurities, Guy B. Taylor and J. H. Capps found that pure acetylene itself did not do any harm; this conclusion is contrary to the opinion previously held. Phosphine PH_3 first appeared not to do any damage either. It was observed, however, that the phosphine was decomposed by coming into contact with the water and the metal of the gasholder. When care was taken to bring the PH_3 undecomposed up to the platinum gauze, the yield of NO went down decidedly, and the figures were in accordance with the statement of Brush that 2 parts of phosphine in 100,000,000 parts of mixed gas were serious in plant operation; there seemed also to be a cumulative bad effect of the phosphine. Sulphuretted hydrogen, on the other hand, appeared to be harmless in concentrations of 0·07 per cent. Further investigation will be needed; but it seems certain that phosphine is a bad poison, and probably the chief cause of the trouble previously attributed to acetylene.

INDUSTRIAL NOTES.

The general labour situation is perhaps slightly easier. There have been no further stoppages; on the contrary, the Clyde men have returned. The Parliamentary Committee of the Trade Union Congress has done useful service in issuing a manifesto to the officials and members of the societies associated with the Congress. There is a reasoned appeal for strict discipline, with an emphatic declaration that unauthorised strikes cannot be tolerated in any circumstances. The leaders of the trade unions, too, are stiffening their attitude, as is evidenced by the fact that the Amalgamated Society of Engineers in the Chancery Division secured an injunction over Friday, on the *ex parte* application of the general trustees, in order to restrain the Kingston-on-Thames and Acton branches from paying out of the funds in their hands maintenance allowance in connection with any strike which was not sanctioned by the society.

The most serious menace at the moment is that by the Miners' Federation, who, at a conference in Stockport on Wednesday, rejected the terms offered by the Government, on a recommendation of their executive and apparently without seriously considering the situation. The miners' principal claims are a 30 per cent. addition to wages, a six-hour day, and the nationalisation of mines. The Government, after carefully considering the situation, issued a luminous statement on the whole question, dealing with wages, hours of labour, demobilisation and other problems. The Government offered an immediate advance of 1*s.* a day (or 6*s.* a week), and promised a comprehensive inquiry into wages, hours, cost of production, and the present and future organisation of the industry, including schemes for joint control of the mines or nationalisation. It is just such public inquiry that is needed to clarify the air, and to make the public realise the tremendous significance of the miners' demand and their menacing attitude. The executive of the federation have now recommended a ballot for or against a strike, but the result is unknown at the time of going to press.

There was a conference at the Board of Trade, also on Wednesday, between the railwaymen's union and the Railway Executive Committee, regarding the railway situation. The proceedings were private, and will be continued. The transport workers have also had meetings to consider the proposals made by the employers' organisations, but in this case also no information is available regarding the situation.

The following two notes are taken from the February issue of *The Federationist*, the official organ of the General Federation of Trade Unions :—

The fear of unemployment is being used by the extremists to create unemployment. This is only their primary object. Their ultimate object is to provoke a revolution in this country and to overthrow all orderly forms of society. The workman who thinks will not be influenced by their propaganda. He knows that one of the fundamental causes of unemployment is lack of confidence. Employment is conditional upon the sale of commodities or the prospective sale of commodities, and if there is no sale or no prospect of sale, then neither men nor women can find employment, remunerative or otherwise. Every threat of a stupid strike tends to diminish confidence and to prevent those who have charge of production and export taking any steps to develop industry and commerce.

To-day in Britain we need at least 500,000 new houses. No man in his senses attempts to build houses, because the building is sure to involve trouble and may involve financial loss. I (Mr. W. A. Appleton) was asked the other day if, in the event of a man starting to build 100 workmen's houses, he could be guaranteed against strikes or "ca canny." I had to answer that in the present chaotic condition of human thought, no guarantees could be given.

In the meantime, men and women and children suffer because of the inadequacy of the housing accommodation.

It is often said that supply begets demand. This is undoubtedly true in some phases of commerce, and unless workmen refuse to follow the dictation of 2 per cent. or 3 per cent. of their number who desire to hold up industry on trivial grounds, they will be faced with loss of markets, particularly overseas markets, and loss of that employment without which they cannot live.

It is absurd to expect that Governments can for any lengthened period subsidise unemployed labour. The best way to avoid catastrophe and starvation is for every man and every woman to look facts squarely in the face, and to commence peace-time production with the least possible delay. During the process they can safeguard their vital interests, but to strike because someone feels that he has been harshly spoken to, or in obedience to the commands of a minority which has ulterior motives, is to invite trouble for themselves and for their children.

In a letter to *The Times*, dated from the House of Commons, the 6th inst., Mr. Kennedy Jones says that two or three years before the war, Sir George Askwith, then Chief Industrial Commissioner of the Board of Trade, was sent to Canada to ascertain how they faced there the problems of irresponsible labour unrest. Mr. Jones calls attention to Sir George's report, and says that the earliest experiment in Canada was made with the railways by an Act which gave to the Government the power to refer any labour differences to a Board of Conciliation, and following this to a Board of Arbitration, the former having the limited powers of offering friendly offices, and the latter enjoying the right to recommend terms of settlement, though these were not enforceable by law. This measure—the Railway Labour Disputes Act, 1903—was successful in so far as it brought the railway men's leaders "to recognise that the holding up of the railway system by a strike was a procedure only justifiable as a last resort, and that it was due to the public that every possible step should be taken to arrive at a settlement before recourse was had to a strike as a means of adjusting differences." The "spirit of the Act" was "frankly accepted," and the "actual results of the policy to both workmen and employers have been advantageous."

Encouraged by this, the Government of Canada then passed the so-called Lemieux Act, the "Industrial Disputes Investigation Act, 1907," whose simple purpose "was to ensure the recognition of the interests of the public as a third party in trade disputes, and with the insistence that that third party, through the Government, should have a voice in regard to a dispute affecting their interests before a stoppage of work takes place." The actual interference with the people in a dispute was confined to :—

1. Industries whose uninterrupted continuance is of high importance to the well-being of the nation (mining, railways, shipping and other public utilities); and

2. A brief suspension of the right to stop as distinct from a complete prohibition of stoppage.

Under the Act disputes in connection with the industries named are submitted to a Board of Conciliation and Investigation, with a view to arriving at a settlement before a strike or lock-out can be legally brought about. At least 30 days' notice of any change affecting conditions of employment, wages, or hours must be given, and, pending the proceedings before a Board of Investigation, to be appointed by the Minister of Labour, the relations of the parties must remain unchanged under personal penalisation of those who act otherwise. Although the finding of the Board can be rejected by either the employers or the workers, a pacific settlement is usually reached, and to this end time for reflection, discussion, official advice and publicity combine to help.

No one would say that the Act pleases every one, or that the outcome is invariably pacific, but at all events it has made strikes fewer and has educated opinion. Sir George Askwith then saw no reason why, with certain modifications, it could not be adapted to the conditions in this country.

Mr. Jones finally quotes one other passage from Sir George Askwith's report—its truth is as great now as it was then: "Carried to its logical conclusion, the claim to cease work at a moment's notice, if acted upon, would make business impossible, and in a civilised community business must be made possible. It is, therefore, not unreasonable for the community to say both to employers and workmen: If you desire to engage in this or that business under the protection of our laws, you can only do so under certain conditions, one of which is that, before bringing about a cessation of work which may seriously jeopardise the public well-being, certain notice must be given."

With reference to our statement on page 184 *ante*, concerning Messrs. Yarrow's scheme for transferring their engineering and shipbuilding activity gradually from the Clyde to their Vancouver establishment, one of the directors of the firm is reported to have stated, in the course of an interview, that one consideration which had influenced their decision was that American workmen handled twice as much material as a corresponding number of men did in this country. The transport facilities were also satisfactory and costs quite low. They could get delivery on the Clyde of steel plates and angles made in America at a price which compared favourably with that of steel plates and angles made at Motherwell.

The spirit of labour throughout the United Kingdom as a whole was another consideration. In America everybody wanted to do as much as he could, and he was allowed to do it, whilst the feeling in this country was that a man should do as little as he could and prevent every other one from doing more than he did. Even if a man wanted to do his best, others would not let him. The doctrine of the restriction of output was a hopeless kind of doctrine, but it was regarded by men in this country as though it were an article of religion. They believed in the doctrine that to restrict output was to spread employment.

The Minister of Labour has stated that in view of the importance of providing industrial training such as is required by large numbers of the demobilised members of H.M. Forces, and civilian war workers, who are being set free from their war occupations, the Government have decided to set up a special department of the Ministry of Labour to deal entirely with questions of industrial training. The Minister of Labour has appointed Mr. James Currie, C.M.G., formerly Director of the Munitions Training Section of the Labour Supply Department of the Ministry of Munitions, Controller of the new department.

This department will not only administer various schemes for the vocational training of discharged soldiers and sailors, of civil war workers of either sex, and of women who are being discharged from the various auxiliary corps, but will, in due course, take over from the Ministry of Pensions the training of disabled men, with the exception of those who require medical supervision or training of a curative nature. Further, the new department will lay down the general lines upon which the training of serving soldiers and of men in hospital will be carried on.

Representatives of the trade unions and employers will be consulted in regard to the proposed systems of training so as to receive their advice and co-operation in the work of the department. Arrangements are also being made to ensure the interest of local authorities in all training work.

The Minister of Labour announces that certain cases have been brought to his notice in which difficulty or uncertainty has arisen as to the course which ought to be followed in regard to giving priority of employment to fully-skilled men over "dilutees," *i.e.*, workers who have during the war been introduced to perform a class of work upon which, before the war, their introduction would have been contrary to the rule, practice or custom obtaining in the trade or establishment concerned. The question is largely, if not entirely, one of restoration of pre-war practices on which a Joint Committee representing both employers and trade unions was set up last November to advise the Government. This committee has met frequently, both separately in their respective panels of employers and trade union members and jointly as a single committee. They have also met and conferred with the Minister of Labour on several occasions. As a result, it is hoped that they will shortly be in a position to make agreed and comprehensive recommendations to the Government, but in the meantime, after consultation with the committee, the Minister of Labour desires to lay down the following general principles for the guidance of employers in dealing with questions affecting priority of employment and discharge as between skilled men and "dilutees" :—

1. Where two workers are employed in the same department and on the same class of work, one a skilled man and the other a dilutee, and one must be discharged, the dilutee should go.

2. If a skilled man is unemployed (whether as a result of discharge from a factory or as a result of demobilisation) and presents himself for employment at a factory where dilutees are employed in the trade in which the applicant is skilled, he is entitled to claim engagement and should not be refused employment at his trade on the ground that there are no vacancies, and that his engagement would involve the discharge of a dilutee.

3. Where, in a single establishment, there are more than one department in which workers engaged on the same class of work are employed, and it is necessary in one department to discharge workers engaged on that class of work, no skilled man should be discharged whilst any dilutees working on that class of work in the same or any other department are retained.

Economic Mission to Poland.—Under the auspices of Sir E. Wyldbore Smith, head of the British Section of the Commission Internationale de Ravitaillement, and in conjunction with the Department of Overseas Trade, a Mission left London on the 4th inst. to investigate the economic conditions in Poland and to inquire into the prospects of British trade with that country. The Mission is in charge of Major MacAlpine, who was until recently in Russia under General Poole, and includes representatives of the Textile Machinery Association and the Federation of British Industries, as well as experts on mining machinery, transport, and questions of finance and labour. The Mission, which has been recommended by the Polish National Committee in London to the various industrial associations in Poland, will be abroad for about two months, and it is anticipated that the information secured will be of considerable value to British trade. Sir E. Wyldbore Smith is also organising a similar Mission to inquire into the conditions in Serbia, and this will start operations in the near future.

THE LATE PROFESSOR G. CAREY FOSTER, F.R.S., J.P.

PROFESSOR CAREY FOSTER, we regret to record died last Sunday, in his eighty-fourth year. With him has passed away one of the few surviving links of the present age with the early days of modern electric science and with the laboratory study of physics in general. For it was owing to his efforts that the first physical laboratory of this country, which offered to students facilities for experimental work of their own, was opened at University College, London, in 1867.

George Carey Foster was born at Sabden, Lancashire, in 1835, the only son of Mr. George Foster, a textile manufacturer and a Justice of the Peace for Lancashire and the West Riding of Yorkshire; later on Foster himself became a J.P. for the county of Hertfordshire, in which he resided. Educated at private schools, he proceeded to University College, London, graduated as B.A. in his twentieth year, and then continued his studies at the Universities of Ghent, Paris and Heidelberg under the distinguished professors of that time. His chief study was chemistry at first, and he became a Fellow of the Chemical Society in 1856; he served for several periods on the council of that society afterwards, and was a vice-president in 1888 to 1892. He investigated the constitution of narcotine and piperic acid and drew up reports on chemical nomenclature and on the state of organic chemistry for the British Association. But physics attracted him more than chemistry, and his main activity was the teaching of physics. An article on heat, contributed to Watt's "Dictionary of Chemistry," drew attention to his wide range of knowledge. In 1862 he was appointed Ward Professor of Natural Philosophy in Anderson's College, Glasgow, and by 1865 he was Professor of Physics in his old college, University College, London. When he vacated this chair, which he occupied after Graham, during the days of Williamson and Ramsay, he was elected Principal of University College; in 1904 he retired. The Athenæum Club received him as a distinguished scientist.

Carey Foster was one of the original founders of the Physical Society of London, which held its first meeting in March, 1873, and was president of that society in 1877 to 1879. A year later he became president of the Society of Telegraph Engineers, for the period 1880 to 1882. In the years 1898 to 1904 he was also honorary treasurer of the British Association, in which appointment Professor John Perry succeeded him. His "Elements of Electricity and Magnetism" appeared in 1896. To the Society of Telegraph Engineers (Institution of Electrical Engineers) he contributed several papers on measurements, especially on the measurement of small resistances and inductances; the bridge arrangement which he devised for this purpose is still known under his name, and was in quite recent years selected by Mr. A. Campbell at the National Physical Laboratory for his determination of inductance. Other papers of his, published in *The Philosophical Magazine* or presented to learned societies, concerned the Siemens pyrometer, absolute electric units, graphic methods of solving electric problems and the relations between mathematics and physics.

Always kindly, courtly, and a man of the strictest rectitude and of true modesty, yet diffident, reserved, not to say shy, Professor Carey Foster was revered by all who came in contact with him, but was not widely known. In some of the sterling features of his character he reminds one of J. H. Gladstone, the chemist, and Robert Kaye Gray, the electrical engineer, the latter of whom was not spared long, unfortunately. Dr. Carey Foster—he was a D.Sc. of Manchester and an LL.D. of Glasgow—kept hale almost to the last, spending most of his time in his home at Ladywalk, near Rickmansworth. It was more old age than the bronchial affection of his last days which carried him away. He had lost his wife, Mary Anne, daughter of the late Mr. Andrew Muir, of Rosebank, Greenock, in 1917. He leaves four sons and four daughters, the eldest of whom is married to Mr. T. Roger Smith, electrical engineer to the Great Western Railway. The funeral is to take place this afternoon at Rickmansworth.

NON-FERROUS METALS.—In order that the trade may know the position in regard to stocks of the important metals, the following particulars are published of the stocks (exclusive of old metal and scrap) in this country in the possession of the Minister of Munitions, on February 1: Copper, 41,882 tons; spelter, G.O.B., 23,905 tons; spelter, refined, 7,734 tons; aluminium, 13,092 tons; soft pig lead, 86,493 tons; nickel, 2,388 tons; antimony regulus, 3,731 tons. It is intended to publish at monthly intervals the stocks held on the first day of each month. In addition to the above, the Minister holds large quantities of scrap, mainly brass of which it is impossible to give any particulars at present.

PROCEDURE FOR ORDERING STEEL MATERIALS.

WE have received the following communication from the Director of Contracts, Admiralty:—

With reference to Admiralty Circular Letter dated June 25, 1918, respecting the procedure for ordering steel materials, the attention of all Admiralty contractors and sub-contractors is called to the fact that the steel superintendents in the various districts, who formerly controlled the rollings at the steel works, are no longer exercising these functions, but their principal duty at present is to ensure that, as far as possible, shipbuilding and any other urgent Government requirements, including merchant shipbuilding, are fully met as a first call on the rolling mills. Firms requiring steel may now place orders direct with the rolling mills, or through merchants or stockholders, as in pre-war days.

The provisions of the circular above referred to are therefore cancelled as from January 31, 1919, but, in view of the fact that a large amount of Government work is still being executed by firms in this country on a "time and line" basis, any firm who has such a contract, and can show that it has been necessary to employ a merchant who has served a useful purpose may do so, but the commission which will be allowed to the merchant or merchants for this service as a charge against the Government funds must not exceed a half of 1 per cent. on the cost of the steel material supplied. This rate of commission has been adopted as that which the Government is prepared to admit as a charge to public funds in the exceptional circumstances of the Government contracts in question, and is not intended to serve as a precedent in respect of ordinary commercial business, nor to cover any special services or facilities that may be mutually agreed between merchants and shipbuilders other than as a charge against Government funds. In the case of supplies ex stockholders' warehouse, the additional charge allowed to stockholders by the Ministry of Munitions permit, dated November 1, 1918, may be made.

As regards contracts which have been taken on a fixed price basis, firms can of course make their own arrangements and obtain the steel required either from the mills direct or through merchants or stockholders, as they desire.

With regard to requirements for shipbuilding purposes, firms are still advised to consult the steel superintendents of the districts as to the mills with which they should place their orders, to facilitate the obtaining of supplies and to ensure that their needs shall be fully met as far as possible consistent with the output from the rolling mills in the various districts.

INTERNATIONAL LABOUR LEGISLATION.

PROGRESS is being made with the institution of a Labour Section of the League of Nations, as discussed in our leading article last week (page 179 *ante*).

The official communique, dated February 12, states that the seventh meeting of the Commission on International Labour Legislation took place that morning. Article IV of the British draft was adopted, which provides that at the proposed International Labour Conference the representatives of the Governments, the employers and the workpeople should be entitled to speak and vote independently, without regard to the views expressed by the other representatives of their nation. This introduces an entirely new principle in the constitution of International Conferences with power to draw up conventions binding on the States represented. Hitherto the delegates present at such conferences have represented the Governments only, and voting had always been by nations. It was felt, however, that in dealing with labour legislation the employers and the workers must be given the fullest opportunity of giving free expression to their views, and that they could not do this if the delegates of each nation were bound to speak and vote as a unit.

Article V was also carried, which provides that the International Labour Conference shall meet at the capital of the League of Nations, unless it decides by a two-thirds majority to meet elsewhere. The Commission then proceeded to discuss the Articles dealing with the establishment of the permanent International Labour Office and the governing body which will direct its work. It was agreed that the office should be established at the capital of the League of Nations as part of the organisation of the League, and should be under the control of a director appointed by the governing body.

DEATH OF MR. GEORGE PAULING.—We regret to announce that Mr. George Pauling, senior partner of the famous firm of Pauling and Co., Limited, occurred last Monday at Effingham, after a brief illness. Mr. Pauling lost his father (a civil engineer in the service of the Indian Government) when only 14 years old, and had immediately to start work, being later on apprenticed to Messrs. Joseph Firbank and Co., with whom he remained for several years. In 1875 he joined the staff of the Cape Government Railways as a junior engineer. In no Government service is there a fair career open to men of exceptional ability, and Mr. Pauling accordingly soon determined to start contracting on his own account, and succeeded, although his sole assets consisted of his brains and magnificent physique. Later on he was joined by his brother, and the two partners, in 1892, secured the confidence of Cecil Rhodes. They constructed the whole of the Rhodesian Railways, in addition to many miles of line in other parts of South Africa. From 1894 to 1896 Mr. Pauling served as Minister of Mines and Public Works in Rhodesia, where he was, moreover, a member of the Executive Council.

PRIORITY OF WORK.

IT was announced on December 11, that priority classifications given before that date for contracts placed by the Admiralty, War Office and Ministry of Munitions would forthwith cease to be operative, except in cases where the contractor is notified in writing or by official notice in the Press that a particular classification is still to be observed for any particular contract.

The Minister of Munitions issued last week an Order almost entirely suspending the operation of the former Order as to priority of March 8, 1917, as regards work of all kinds. The effect of such suspension is as follows:—

In the case of orders placed on and after February 1, 1919, whether for Government or civil work, priority need only be given when special priority directions in writing to that effect are received from the Priority Department. In the absence of such directions no priority need be given to orders placed after that date by or on behalf of the Admiralty, War Office or Ministry of Munitions.

Such special priority directions issued after February 1, 1919, will be strictly limited to those very exceptional cases in which it is deemed to be essential in the national interest that priority be given. Contractors and others who may receive such priority directions in respect of any order for work or materials are empowered to pass on these priority directions to sub-contractors for work or materials required as a component part of that order, and such directions will be binding on the sub-contractors as hitherto.

Priority certificates and permits issued before February 1, 1919, will cease to be operative on and after March 1, next. This applies to all priority certificates and permits, whether issued by Government departments or by firms themselves, on the form of certificate obtainable from Post Offices.

Forms of certificates will not be obtainable from Post Offices after March 1 next. Instruction as to the manner of transmitting priority directions to sub-contractors after that date will be embodied in the new form of permit to be issued when special priority directions are given.

Any question arising out of this notice as to the validity of any priority certificate or any other matter should be addressed to the Controller, Priority Department, Ministry of Munitions. The address of that department is now 10, Great Stanhope-street, London, W. 1, *not* Caxton-street, London, S.W. 1.

ROYAL AGRICULTURAL SOCIETY OF ENGLAND.—The Royal Agricultural Society of England, after an interval of two years, has now issued the prize sheet for live stock, poultry, rabbits, produce, implements, &c., at the Show of the Society to be held at Cardiff from Tuesday, June 24, to Saturday, June 28. The total value of the prizes offered (inclusive of champion prizes, special prizes, and medals) is 10,800*l.*, of which 1,035*l.* are contributions from the Cardiff Local Committee, 3,547*l.* from various breed societies, and 505*l.* 10*s.* from other sources.

HARBOUR SHEDS OF REINFORCED CONCRETE IN SUMATRA.—Sheds formerly constructed of corrugated iron have during the war been built of reinforced concrete and have the advantage of being cooler and less likely to be infested with rats, says *De Ingenieur*, The Hague. They are easily cleaned with water from a hydrant, offer resistance to burglars, are more durable, and of neat appearance when properly designed. These buildings have, however, the disadvantage of being heavier, and therefore require more expensive foundations where the ground is bad, they are not portable, and the concrete may crack and become leaky.

THE BIRMINGHAM SMALL ARMS COMPANY.—In the course of an interview, Sir Hallewell Rogers, M.P., chairman of the Birmingham Small Arms Company, stated that the call of the Government on his company during the war for increased output in rifles, Lewis guns, aeroplane parts and other material had been simply enormous and persistent, and that in response to that call the company had very extensively increased their buildings and plant. Now that Government contracts were about to terminate, the Board were fully alive to the possibilities of the situation. Fully recognising the necessity of finding work for their employees and of keeping up the supply of such guns and small arms as the Government thought requisite, as well as increasing their private trade in small arms, they were adapting their extensive surplus factory space and plant to the construction of cycles, motor cycles, cycle fittings and specialities on a very large scale. Sir Hallewell emphasised the fact that the requirements of the public and of the trade in this particular department would be most adequately met in every respect. In order to facilitate management, the cycle, motor-cycle, cycle fittings, and specialities department was about to be arranged as a separate company, under the name of "B.S.A. Cycles, Limited," with Mr. C. A. Hyde as managing director, the whole of the shares in the separate company being held by the Birmingham Small Arms Company, Limited. Mr. Hyde had been well known in the trade for thirty years; he was the inventor of the Hyde free wheel. He was, besides, president of the Cycle and Motor Cycle Manufacturers and Traders' Union, Limited; chairman of the Executive Committee of the Engineering and National Employers' Federation, Birmingham and district; and a member of the Council of Federation of British Industries; of the Executive Committee of the Association of All-British Motor and Allied Manufacturers, and of the Local Advisory Committee to the Ministry of Labour.

THE RAILWAY PROBLEM.

To the Editor of Engineering.

Sir,—I see it is stated in your issue of January 3, that I, together with others, am acting in an advisory capacity on a committee formed by the Board of Trade to consider what is to be done with the railways after the war.

I felt much honoured to be nominated on this committee, but, in view of what has happened lately, I think it well to point out that this committee has never yet had before it any scheme for consideration in connection with this subject. Neither has it been called upon to express any opinion as to what should be done after the war with the railways.

The committee has held two meetings during a period of many months, and I have made the following suggestions:—

1. Before the committee is asked to pronounce any opinion, a statement should be drawn up and a balance-sheet presented, including the estimated value of the services rendered to the Government by the railways under the control of the Railway Executive Committee. It may not be possible to give the exact number of men that have been moved in connection with the transport and return of troops, but it must be possible to ascertain the train miles involved in this operation, and an average value could be put upon this service.

As to the movement of munitions of war and other commodities for the Government which have been transported free of charge, there must be accounts kept of all this work in the various railway companies' books. Though it has frequently been said that the railways have not been able, in view of the extra cost of maintenance and extra wages paid, to meet their expenditure without Government aid, there is no direct evidence of this given in any accurate accountancy. It is impossible to confirm this by any figures before the public.

2. It must be clear that it is in the public interest that proposals should be put forward (prior to this committee formulating recommendations) either by the railway Executive Committee and/or by the best experts connected with the railways themselves giving their views from the railway managerial point of view how best the railway situation after the war ceases should be dealt with.

Personally, I have a completely open mind (though I have some ideas of my own as to the way to deal with the railways after the war), but it must be evident to all that those who have so ably, not only prior to, but during the war, managed our railways in the general interests both of the stockholders and the public, and who have succeeded, notwithstanding reduced personnel and rolling stock, in carrying anything from 55 per cent to 60 per cent. more freight and many more passengers than passed over their lines in times of peace, are best fitted to make preliminary proposals for the consideration of this or any other committee.

As things now stand, either with knowledge not possessed by the committee, or on the advice of some expert opinion not yet made public, the Government has determined, it is reported, to adopt the policy of nationalisation of British Railways in some form or another. I submit that without such information as I have asked for, it is not possible for anybody to recommend what form the nationalisation of railways should take in this country. It is clear, however, in the railway history of other countries, that all forms of nationalisation have not been a success, and it is incumbent upon us, in view of the enormous outlay that will be necessary to acquire the rights of railway share and debenture holders, as well as safeguard the public interest, that any scheme should be very carefully considered, and all evidence brought forward in the completest detail and given the fullest consideration at the earliest possible moment.

Yours faithfully,
E. W. Moir.

10, Victoria-street, Westminster, S.W.
February 7, 1919.

"COAL SAVING BY THE SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

To the Editor of Engineering.

Sir,—When Mr. Casmey has succeeded in burning 1 lb. of coal in 12 lb. of air he will be able to measure the temperature produced. Until then it is idle speculating about it. It is an even more idle proceeding to make assumptions regarding temperatures and from those assumptions calculate heat losses. Doing so will not enable anyone to operate a steam boiler economically.

No steam boiler can be economically operated if the natural laws governing combustion are deliberately set at defiance in the manner scientific controllers advise.

Efficiency of combustion is totally independent of the chemical composition or the calorific value of any fuel. It depends entirely on the quantity of heat liberated in a certain quantity of air. The relation between the quantity of heat and the quantity of air is as fixed and immovable as the mechanical equivalent of heat itself. I gave the relation in my last letter, viz., for maximum efficiency 620 British thermal units per pound of air used.

As Mr. Casmey has not yet investigated combustion results from that standpoint he is not in a position to discuss the efficiency of combustion intelligently. The fact that my original observations were made over twenty years ago does not in any way affect their accuracy. Every carefully-conducted combustion test since then provides ample confirmation. It may have escaped Mr. Casmey's notice that steam boilers have been in use for power purposes in this country for over 200 years. It would be a curious reflection that every engineer in charge of boilers during all that time had been ignorant of the manner in which a boiler should be economically operated. I am not a believer in supermen who wrest secrets from Nature. The manifestations of natural laws are open to the observation of all men whose intelligence and training fit them to formulate the effects of their operation. If until now certain facts governing combustion have not been within the knowledge of Mr. Casmey, it does not follow that such facts have neither foundation nor essence of truth. It is to be regretted that, after reading my letter on page 139, Mr. Casmey did not turn to page 159 of the same issue. On that page he would find it amply confirmed that "by admitting more air to the furnace" the efficiency of a boiler with economiser was increased 19 per cent. Those of your readers who are in the habit of exercising their intelligence will recognise the practical commonsense and intelligence displayed in the sandwich system of stoking with a mixture of bituminous coal and coke laid in layers on a grate. They will, of course, recognise that the chief function of the coke is that of opening up the mass of fuel to the passage of air. That I regard as an example of real scientific control.

Yours truly,
Jas. Dunlop.

190, Bellfield-street, Dennistoun, Glasgow,
February 8, 1919.

CAPITAL AND LABOUR.

To the Editor of Engineering.

Sir,—I have for a long time past considered that many of the strikes and misunderstandings between Labour and Capital might be avoided, and more harmony and good feeling be brought about, in a simple way, by arranging for Labour to be represented on the boards of directors of all railway companies, and large manufacturing companies.

My proposal is, that in each case, the workmen should be allowed to elect as their representatives on the Board a certain number of directors, in proportion to the numbers employed, where they could explain to their fellow directors the men's views and grievances, and suggest remedies for them, as well as from time to time bring forward proposals for improvement in working and output made by men. The labour directors would have to take enlarged views of the difficulties of successful management, and of the great responsibilities involved; and both Capital and Labour directors would, by frequent intercouse and discussion, acquire mutual regard and respect, each for the others; and also see that to every question, there are at least two sides to be considered.

Having been chief engineer and then manager of a large railway system of 1,700 miles, in India, I write with practical knowledge, and thirty-five years' experience in the management of large bodies of men.

It seems to me that my proposal is a practical one, and easy to try; involving none of the difficulties of profit-sharing and similar proposals, and it would also be inexpensive.

Yours truly,
Edward N. Stoney, C.I.E.,
Mem.Inst.C.E.

The Gables, Coonoor, India,
November 30, 1918.

Disposal of Surplus Government Property.—The Secretary of the Ministry of Munitions announces that, in accordance with the decision of the Government to establish a central authority for the disposal of all surplus Government property, the Minister of Munitions has approved of an organisation for this purpose. An Advisory Council has been appointed to advise the Minister on such questions of policy as may be referred to them. The organisation consists of a Board directly responsible to the Minister, to be called the Surplus Government Property Disposal Board. The departmental organisation is divided into the following 17 sections to deal with the different classes of property arising for disposal; at the head of each of these sections is a controller, responsible to the Board:—*Names of Disposal Sections*: (1) Lands, Buildings and Factories and Furniture; (2) Huts and Building Material; (3) Plant and Machinery; (4) Timber; (5) Mechanical Transport (including Tanks, Agricultural Machinery); (6) Horses and Animals; (7) Textiles, Leather and Equipment; (8) Railway Material, Transportation Stores, Road Repair Machinery; (9) Electrical Instruments, Telephones and Telegraphs; (10) Medical Stores, Equipment and Instruments; (11) Ferrous Materials; (12) Non-Ferrous Materials; (13) Chemicals and Explosives and Chemical Warfare Material; (14) Factory Consumable Stores; (15) Aircraft Equipment; (16) Watercraft and Dock Plant; (17) Miscellaneous Stores. The 17 sections have been arranged in groups, each group being under the general superintendence of a member of the Disposal Board. In carrying out the duties entrusted to him, each Controller will have the assistance of an Honorary Advisory Committee of men whose special knowledge and experience will ensure that the various classes of property are disposed of to the best advantage. In accordance with arrangements made with the various Government departments concerned, no property surplus to the requirements of those departments will in future be disposed of except through, or by arrangement with, the Disposal Board. This equally applies to surplus stores in the various theatres of war. A special section is being set up to deal with sales to neutral countries. Communications should be addressed to the Secretary, Disposal Board, Armament Buildings, Whitehall Place, S.W. 1.

THE VARIATION OF MEASURING INSTRUMENTS.

*Variance of Measuring Instruments and its Relation to Accuracy and Sensitivity.**

By Frederick J. Schlink.

I. INTRODUCTION: FUNDAMENTAL DEFINITIONS.

The distinction between accuracy and sensitivity in engineering and physical measuring instruments is not always carefully maintained in the discussion and calibration of such instruments. In fact, certain phases of the meaning of these two terms have not been clearly expounded. The fundamental concepts are, of course, clear:—

1. An instrument is accurate when its indications accord with the true values of the quantity being measured.

2. An instrument is sensitive when a change in the quantity being measured is accompanied by a change in the indication of the instrument.

II. ACCURACY.

Neither of the above definitions is of much utility until amplified and expressed quantitatively. In the first place, instrumental accuracy as the term is defined above, is only an ideal, since it is impossible to obtain perfect exactitude in the reading of any measuring instrument on account of divers unavoidable mechanical limitations imposed by the co-action of the working parts; the existence of friction; alterations in the properties of measuring elements with time and with changes in the environment of temperature, atmospheric pressure, humidity, &c.; and normally uncontrollable variations in the manner, frequency, and rate of operation.

In the common measurements of industry and commerce sufficient accuracy is sought to permit of dispensing with the use of corrections, allowing the employment of observed readings directly, partly to eliminate errors of calculation and partly to enable such indispensable instruments as pressure gauges, measuring rules, micrometer calipers, &c., to be used by persons not possessed of special technical training. In the laboratory, on the other hand, the numerical equality of the instrumental reading to the true value of the quantity being measured is not essential (except for the arithmetical convenience which results from having small values for the corrections) since the exactness of the work will usually require that the corrections of the instrument be determined numerically at relatively close intervals throughout its reading range, unless those corrections are very small. The readings of the instrument, therefore, will be corrected before conclusions are finally drawn from them. By so doing the convenience requisite in industrial or commercial instruments is sacrificed, while exactness is served.

Instrumental accuracy is usually expressed numerically in a negative sense, by defining the error or correction for various values of the quantity being measured. The error arising from whatever source, observed in an indication of the instrument, divided by the true value of the measured quantity may be termed the relative or specific inaccuracy at a given reading, the negative term being justifiable on the basis of custom and ease in application. With this in mind it is seen that specific accuracy may be expressed as the ratio of the value of the quantity being measured to the error of the instrumental indication at that value (this, of course, being the reciprocal of the quantity defined above). The ratio expressing instrumental accuracy, while not of value in the ordinary use of instruments, will be of service in rating the performance of an instrument.

III. SENSITIVITY.

1. Definition.

By definition, any instrument which shows a change of reading for any change, however great, in the quantity being measured, is sensitive or has sensitivity. Clearly, then, this term has little significance until means are available for expressing it numerically. For particular instruments, especially those read by null methods, sensitivity has often been expressed in terms of the smallest change of value of the quantity being measured capable of causing a perceptible response or change in the reading of the instrument. Expressed in this manner, the term is necessarily unscientific and loose in its significance, since differences in the observers' acuteness of perception, or personal sensitivity, as it might be called, would result in widely varying estimates of the sensitivity of the instrument; moreover, using this criterion, we should fail to distinguish between insensitiveness and sluggishness, a distinction which, as later considerations will show, is an important one.

For example, the sensitivity of scales and balances was long defined in terms of the smallest added load which would effect a perceptible change in the position of equilibrium of the beam or pointer. The current method of expressing sensitivity in terms of measured motion at the pointer tip is an improvement, and the best current practice is to define the sensitivity of a balance as the number of linear units by which the rest point is displaced—when measured at the pointer tip—for a unit change in the load on the load pan or platform. Balance makers have not commonly adopted this practice, however, and it is still customary with them in their catalogues to refer to balances as being sensitive to a given number of milligrammes when no definite value of pointer motion is meant, but merely a visually perceptible one (probably somewhat less than a millimetre). For instruments of this character, even the method of basing the sensitivity

* Paper issued by the United States Bureau of Standards.

on motion at the pointer tip does not seem satisfactory, since it depends upon the accident of pointer length, and, on the basis of this definition, a given balance can be endowed with almost any desired sensitivity by the use of an optical lever or other means of high magnification.*

A better basis would be the angular deflection of the rest position of the beam per unit addition of load to the load pan, the first expressed in radians, and the second in grammes. True, this manner of expression is open to an objection from the strictly practical point of view, in that no balance, and in fact few measuring instruments commonly read by the null method, are ever subjected to a deflection of so much as a radian; the unit of angle suggested is simply larger than the practical deflection, instead of being smaller, as custom might seem to demand. All actual measurements of sensitivity, however, must for other reasons be restricted to small deflections, principally because the sensitivity itself is subject to more or less regular variation over the scale of deflections; the deflection used in determining sensitivity must be small enough, therefore, that variations over that range of deflection are quite negligible.

2. PASSIVENESS DISTINGUISHED FROM INSENSITIVENESS.

Certain aspects of the action of friction in introducing error into instrumental readings have been discussed before, notably in Gramberg's "Technische Messungen" and in Weinstein's "Physikalische Maasbestimmungen."† The variance error to be discussed in the next section has its rise in friction, in that the divagation of reference points or axes from the paths or positions determined under the assumption of a perfect and ideally fitted mechanism, is an effect which would not obtain except for the resistance which the friction offers against the taking up of the minimum or most stable positions by the journals. That action, dependent though it is upon friction, is of such definite importance from another viewpoint that it will be treated separately.

Simple frictional resistance to turning or sliding, however, has a bearing upon the ordinary concepts of sensitiveness which should be mentioned in the present connection. Its effect is to retard or delay the motion of the indicating element for both increasing and decreasing values of the quantity being measured. The amount of the static friction will be roughly proportional to the restoring force in the system, so that in the usual case, as the reading increases, there will be a tendency for proportionate increase of mechanical hysteresis due to friction, and the error which it causes will be greater, the less the forces available to effect motion of the mechanism, for a unit change in the measured quantity.

The immediate effect of turning or sliding friction is to prevent response of the instrument reading to certain small changes in the measured quantity. On this account it becomes necessary to draw a distinction between sensitivity and immediacy of response. It is clear that if our first and commonly accepted definition of sensitivity be strictly adhered to, we will come upon the peculiar circumstance of an instrument having zero sensitivity whenever any finite change in the quantity being measured is accompanied by no deflection whatever of the indicating element. Nevertheless, exactly this occurs in an instrument having friction or lost motion. In fact, it is often true in instruments of less precise character that a considerable change in the measured quantity can be effected without the occurrence of any motion whatever of the indicator; this period of inaction of the indicator persists during the taking up of slack and the overcoming of the static friction of the operating parts, much as the first pull of a locomotive on a train fails to produce motion of the caboose until the slack between all the cars has been taken up, and until the static tractive resistance of all the cars has been overcome.

With this in mind, it will be admitted that the usual definition of sensitivity leads to an absurdity, in that the determination of the sensitivity of an instrument would depend upon the absolute rather than the relative magnitudes of the quantities entering into the observation, and in that it would, moreover, involve an abrupt changing over from zero sensitivity to finite sensitivity. In view of the irrational nature of any such assumption, the definition of sensitivity must be modified, thus: Sensitivity in an instrument is the rate of change in the indication of such instrument with respect to change in the quantity being measured, it being necessarily assumed for the purposes of this definition that friction and lost motion in the mechanism have been eliminated or are negligible. (A similar postulate applies to the analogous determination of the scale value in instruments graduated directly in the units of the quantity being measured.) We thus distinguish between instrumental passiveness (or sluggishness) and instrumental insensitiveness, a distinction which, so far as known to the writer, has not hitherto been set forth.

The factor of passiveness may then be determined by noting the smallest alteration in the quantity to be measured which will produce any change whatever in the indication of the instrument. The amount of the least alteration in the value of the measured quantity producing instrumental response, divided by the initial value of the measured quantity, may be called the passivity of the instrument at that point.

For the present purpose, then, we must revert to the term "perceptible movement," which has properly been rejected in so far as it concerns definitions of sensitivity. This is logical on the ground that the passiveness evidenced by delayed response has been overcome so soon as any motion whatever of the indicating element has taken place. This factor when present can be observed in the complete hysteresis loop of the instrument, as measured by the length of the horizontal line which appears in the measured quantity—indication curve of the instrument at points of reversal of reading. (See under Backlash, *infra*.) Passiveness then is a special case of the phenomenon of variance, the factor discussed in the section immediately following. The present section has been introduced in this order on account of the intimate relationship of passiveness to the determination of sensitivity, observations of which are peculiarly subject to error in the presence of high instrumental passivity.

IV. VARIANCE.

1. DEFINITION.

The third important factor to determine in the calibration of a measuring instrument is that of variance, which is defined as the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, after a steady reading has been attained, the environment remaining unchanged. This quantity, which overlaps the passiveness factor defined above, may also be called the range of uncertainty of indication, in that it represents the range within which the readings of the instrument may be expected to lie when all causes of variation save those inherent in the instrument are eliminated. The specific variance or variancy (the same etymological distinction being maintained as heretofore) may be defined as the ratio of the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, divided by the value of the measured quantity itself, the same assumptions applying as above as to the attainment of a steady state of indication (see Drift, *infra*) and as to the maintenance of unchanged environment. This factor has rarely been determined in tests of measuring instruments; ignoring it in their use, as is commonly done, may cause appreciable error, and it is therefore important that it be recognised or expressed.

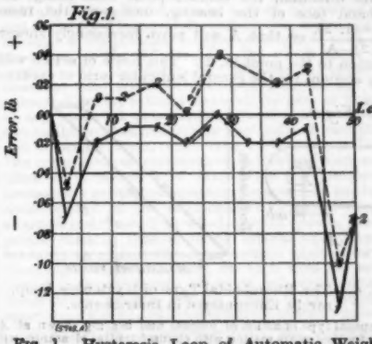


FIG. 1. Hysteresis Loop of Automatic Weighing Scale of the Cam-Pendulum Type (comprising no Elastic Force-Measuring Elements).

Note the manner in which the curve of decreasing readings reflects the aberrations of the curve of increasing readings, with a distinct tendency toward wider separation at the middle of the load range, so that the hysteresis loop would have a distinctly lenticular form, if the median line or mean error curve were rectilinear.

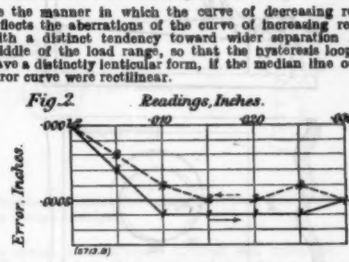


FIG. 2. Hysteresis Loop of Dial Indicator of the Screw-Train Type, having High Multiplication, an Instrument much used for Direct Reading of Small Displacements and other Linear Magnitudes.

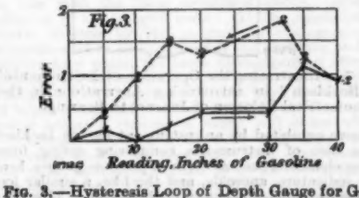


FIG. 3.—Hysteresis Loop of Depth Gauge for Gasoline Tank, a Diaphragm Type of Pressure Gauge Graduated in inches of Gasoline. (Ordinates in inches of Gasoline.)

In the case of the usual direct-reading instrument, the variance is disclosed as the displacement observed between the upward and downward branches of the hysteresis loop when the instrument is subjected to a complete cycle of operation from a lower to a higher indication, returning again to the lower indication, while plotting point by point the instrumental readings against actual values of the quantity to be measured. It is obvious from the nature of the hysteresis loop and the causes underlying it that the amount of the variance will depend upon the previous history of the instrument and, specifically, upon the immediately precedent cycles of operation through which the mechanism has moved.*

The hysteresis loop for a measuring instrument exhibits many of the characteristics of that of a structural material under stress, in that the loop is the narrower the less the range of operation (corresponding, in the case of the stressed specimen, to the range of stress); and in that it is the narrower the more delicate and workmanlike the construction, somewhat as the hysteresis loop of a stressed specimen is reduced in area with homogeneity and fineness of structure.

This curve, showing the readings (or errors in the readings) of the instrument over its whole scale range, plotted against corresponding values of the quantity being measured, for increasing and decreasing values of that quantity, is a valuable and, in fact, indispensable index to the operating characteristics of an instrument and affords distinctive and easily interpreted information regarding defects of design and workmanship discoverable with certainty in no other way.

Consider the curve shown in Fig. 1, which is plotted from observations on an automatic or self-indicating weighing scale. This particular scale is one in which the load is equilibrated by the variable turning moment of a pair of oppositely rotating pendulums mounted on ball bearings. The effect shown, therefore, is certainly not the hysteresis of inelasticity, such as would be observed in the test of a spring scale, although, admittedly, elastic hysteresis is present in very small and negligible amount in every instrument, due to variations in the working stresses (in this case, in the load-sustaining parts of the scale which transmit the forces from the platform to the pendulum). The sources of the hysteresis exhibited in the fixture are manifold; though diverse in apparent character, however, all are expressible as backlash or are closely analogous to it.

Figs. 2 and 3 show other typical examples of hysteresis effects, the instrument of Fig. 2 having no source of hysteresis of inelasticity, while that of Fig. 3 does.

In one case so important was the recording of the backlash characteristic that the writer, in the inspection on a contract comprising 1,200 automatic scales, found it advisable to note for each scale complete sets of reading taken at suitable intervals over the whole range of graduation for increasing and decreasing loads, the results of the test observations being plotted directly into graphs like that of Fig. 1. The median line of the loop so obtained gave the characteristic error of the scale, correctable by suitable alteration of the weights of the pendulums and of the contour of the cams upon which were wrapped thin metallic tapes transmitting the load from the platform system to the pendulums. The width of the hysteresis loop, moreover, gave a good index of the workmanship of pendulum bearings and connections.

It will readily be appreciated how valuable is the information which such a graph affords in evaluating the fundamental characteristics of an instrument and in indicating defects in workmanship and design.

2. TYPES OF VARIANCE.

In all instruments which use a spring element for equilibrating the changes in the measured quantity directly or through conversion from displacements to forces, a source of variation exists in the imperfect elasticity of such a spring, whose changes in shape or dimensions are always to some extent irreversible. This imperfect reversibility of the stress-strain relation implies a hysteresis effect in the calibration of the instrument. Apart from this, we have the effects of imperfections in the mechanism itself, next to be discussed, as evidenced in such parts as journals, bearings, and gearing.†

(*a*) *Backlash.*—The function of turning pairs in a

* The author is not unmindful of the practical limitations upon the use of a high magnification with a balance or other measuring instrument of mediocre quality. This question will be discussed later in considering the factor of variance.

† See also the author's paper: "A Stabilised Platform Weighing Scale of Novel Design," Technologic Paper No. 106 of the Bureau of Standards, 1918, pages 9 to 12.

* Much of the discussion of this paper relates directly only to mechanical instruments whose indications are of a reversible character; of another class are time-measuring instruments and some types of integrating instruments in which the readings cannot be made to repeat or recur at will; these are not completely amenable to the present treatment, but require special consideration. That this distinction is fundamental is clear from the fact that a chronometer cannot be said to have sensitivity, since time is in its very essence epochal and irreversible. These methods do, however, apply with complete validity to many devices and mechanisms not always considered to be comprised in the term "instrument," *e.g.*, telephone receivers and transmitters and phonograph reproducers, and a large class of controlling or value-limiting mechanisms, such as thermostats, barostats, hygrostats, voltage regulators, engine governors, and carburettors for internal-combustion engines, all of which are in fact in large measure subject to perturbations arising from effects to be classed as irreversibility. This is true, moreover, of liquid-column instruments such as mercurial barometers, for even in such instruments resistance to motion does not actually vanish at zero velocity of the liquid. Imperfect reversibility in measurable amount is known to exist in mercurial barometers and other liquid manometers.

† There are, of course, other sources of lag that are evidenced as loops in the calibration curves of instruments. As typical examples may be mentioned the

measuring instrument is distinctly different from that which they fulfil in a machine. In a machine the exact maintenance of the distances between centres of rotation of its elements is not ordinarily a fundamental requisite. Except in rare instances, only approximate invariability of distance relationships in the linkwork is required. In a measuring instrument, however, the whole result to be obtained depends upon the maintenance of constant or at least determinate intervals between the parts of the mechanism which transfer the forces or motions involved from the point of their reception to the point of registration or indication. This, expressed kinematically, requires that links must have a constant virtual length (if comprising only lower pairs) or determinate virtual length, constant and definite for any given configuration of the linkwork (if comprising higher pairs).

It will readily be seen that the presence of slack or backlash in the mechanism of an instrument will have the same effect on the indication as an equivalent advertent displacement of those parts of the instrument receiving the force or displacement. The term backlash is here used to imply only looseness of fit resulting in play of the co-acting parts. Such irregular and uncontrolled defects in the linkwork itself are usually, in fact, magnified at the point of registration, owing to the multiplication of the motion from the receiving to the registering element.

The effect of backlash is usually assumed to be that shown in the hysteresis loop at B in Fig. 4, viz., a rhombus of which the two parallel horizontal sides (magnified, it may be, by the multiplication of the mechanism) correspond exactly with the geometrical clearance in the bearing. The portion a b represents the phase of load addition during which no change of indication occurs, pending the taking up of the lost motion. c d is the corresponding phase at the beginning of the returning portion of the curve. During this phase the pin or journal is assumed to be returning to contact with the opposite contact face of the bearing.

As a matter of fact, the only defect of workmanship which could produce this type of error is typified in the view at the left in Fig. 4, in which a round pin or journal co-acts with an oval bearing, the lesser diameter of the bearing being exactly equal to the diameter of the journal. In this case the clearance of the journal in its bearing occurs in one direction only. Such a bearing detail could occur but rarely, and then only in instrumental of which the bearings were badly worn; moreover, a hysteresis loop of the form shown in B could hardly occur in any rationally designed instrument since some portion of the mechanism is usually restrained by a counterweight or spring (often a hair-spring at the indicator spindle) to the end of keeping the journals in contact with the same general faces of the bearing, thus providing what is known as force-closure of the linkwork. Such a hair-spring cannot, however, eliminate all backlash effects so long as a finite "running" clearance exists between the components of the turning pairs, as will be shown hereafter.

Were an instrument to comprise only the form of backlash just defined, a constant displacement would exist between the upward and downward branches of its hysteresis loops, so that a fairly definite and useful correction could be applied for the backlash error, if only the phase of the instrument movement were known.

As a matter of fact, the shape of the hysteresis loop for an instrument is lenticular, and not dissimilar to that of an imperfectly elastic structural specimen under stress. (To be sure, such a specimen with an applied extensometer is itself a measuring instrument, being a spring-controlled weighing scale with, ordinarily, a stiff spring and high magnification.) The reason for this shape of the hysteresis loop will be noted by reference to Fig. 5. Let 1 and 2 be two conjoined links of the mechanism of a measuring instrument. For the sake of concreteness, we may consider them comprised in the simplified hair hygrometer shown in the diagram at the left of the figure. During the operation of the hygrometer the links 1 and 2 rotate relatively to each other about some more or less definite centre (1, 2). The kinematic consideration of such a jointure would, of course, be to assume perfectly circular rotation about coincident geometrical centres of the journal and bearing. For most kinematic problems this approximation is amply close. In instruments, however, as has already been pointed out, the whole performance of the device depends upon the definiteness of the geometrical configuration at a given value of the quantity being measured. Let us therefore examine into the action taking place in a single bearing having a loose journal. As 2 rotates relatively to 1—assuming that force-closure exists to keep the bearing and journal in contact at some point, and the hair 3 taut, as would be the case in any well-designed instrument—the journal in part rolls and in part slides around the interior of the bearing, its centre describing the arc of a circle whose radius is equal to the difference in the radii of the journal and the bearing. The point (1, 2) then for ordinary motions of the instrument will have a motion in this arc, which motion is superposed on the pure self-rotation which it derives from the intended operation of the mechanism. It is seen, therefore, that the motion of the pointer tip over the graduated reading scale does not bear a simple geometric relation to the lengthening or shortening of the link 3, being in fact distorted by the complex motion at (1, 2).

In the case of a horizontal spindle turning in ball bearings, the exact performance may be somewhat different from the above, although the effect is the same. In cases which have been examined, the ring of balls surrounding the spindle appears to roll as a unit with the turning of the spindle, while the spindle itself remains in contact with, and has its weight supported by, one pair of balls near the bottom of each ball race. As the ring of balls turns, due to the rolling of the individual balls in the race, the spindle is carried upward an amount depending roughly upon the radial clearance between the spindle and the interior of the ring of balls.

The effect of this divagation of the point (1, 2) in introducing error in the instrument reading may be simply expressed as the variation which it produces in the leverage ratio (in this case, in the two arms of the link 2). As the pin shifts to the left and upward in its bearing, a point which is the instantaneous centre of relative motion of the two links and which lies at a determinate point situate between the centre of the bearing in 1 and the contact point m_1, shifts in such a way as to decrease the ratio of the two arms $\frac{(3,2)-(1,2)}{(1,2)-A}$. On this account point A moves increasingly faster in relation to the point (3, 2). When link 2 rotates in the opposite direction, the contact point rises along the right-hand face of the bearing, increasing the ratio $\frac{(3,2)-(1,2)}{(1,2)-A}$, so that A will move increasingly slower in relation to the point (3, 2). This mode of action will clearly account for the general lenticular form of calibration curve exhibited by an instrument having backlash. In the case of instruments comprising spring force-resisting elements, such as occur in pressure gauges, heat-engine indicators, aneroids, and the like, a similar loop will arise from inelastic action of the spring. This effect will be combined in the calibration curve with that due to backlash.

Fig. 4.

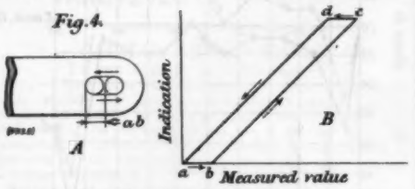


FIG. 4.—The Rhomboidal Type of Hysteresis Loop, rarely Encountered in Instruments.

The unusual type of action of journal and bearing shown at *A*, or of toothed gears mating with circumferential clearance, will produce this form of calibration curve.

Fig. 5.

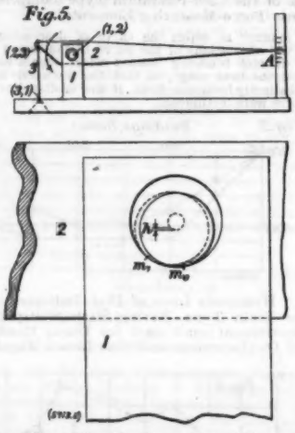


FIG. 5.—Illustrating the Operation of Instrumental "Backlash" in Introducing Aberrations in the Geometrical Relation of Journal to Bearing.

The limiting amount by which the point of contact may be displaced from the lowermost or most stable point of the bearing could, if necessary, be approximated from a knowledge of the weights of the parts, the direction and magnitude of the other forces involved, and the coefficient of friction of the materials of the journal and the bearing.

When the maximum sidewise displacement of the centre of the journal is reached, a more or less steady* state of relative slipping between journal and bearing takes place, so that in so far as concerns hysteresis from journal action, it is to be expected that the backlash loop corresponding to this portion of the operating range of the instrument will be flat. The loop will, therefore, be made up of three phases: A lower lenticular portion; a middle oblong, approximately straight-sided portion; and an upper lenticular portion. This state of affairs has been approximately confirmed by experiment. It may easily be that the calibration curve will not form a completely closed loop since local roughness and variations in surface conditions of bearing and journal may operate to prevent complete reversion of the parts to their initial positions. Specifically, this may occur when the force designed to effect force-closure of the system is insufficient in amount. The amount by which the loop fails of closure may be termed the set. The relative or specific set is the ratio of this residual deflection divided by the deflection which occasioned it.

In cases in which a link typified by 3, functions as a means of transferring or modifying a motion from 2 to 4, the effect of the interior rolling of journals in bearings is to lengthen link 2 and shorten link 4 for rotation of 2 and 4 in one direction, and *vice versa* for rotation in the other direction, thus again acting to widen the hysteresis loop.

Clearance between the engaging teeth of gears and toothed racks which appear in many instruments introduces backlash effects of the same general nature as those outlined above. In many cases the backlash effect in a gear train will be superposed upon that of the journals and bearings of the train. In every case there are certain phases of motion in which such effects will be additive. In gear trains, moreover, there is especial likelihood of occurrence of the true backlash type of loop shown in Fig. 4 at B, since clearance at the pitch line will tend to result in actual discontinuity in the transference of motion from one part of the train to another, whenever the direction of rotation is reversed.

(*b*) *Irregular Variance.*—In the case of instruments which are characterised by poor workmanship or are in a state of ill repair, the hysteresis loops obtained on successive runs may be far from concordant in either shape or magnitude, this condition being of course a result of inaccurate fitting of such serious order that variations in the friction and journal displacement, even for a particular indication, become significant. In the case of instruments of this kind, the variance may be well expressed and defined by plotting frequency curves of the readings or errors obtained for a given value (or for a series of definite values) of the measured quantity repeatedly applied.

One series of points will be plotted for readings taken at varying rates and amounts of increase of the measured quantity terminating in the value corresponding to the particular point of the scale under investigation, and another set for decreasing values terminating at the same point. Such a curve, in which frequency of occurrence of a particular reading or error is plotted against the true value of the measured quantity at that reading, gives the probability of occurrence of any amount of variation from, say, the mean instrumental reading.

A series of such frequency curves taken at various parts of the reading range may be plotted as shown in Fig. 6, in which case the surface which may be conceived of as enveloping the family of probability curves when they are thrown into three dimensions, will enable one to determine the probability of a given error at any point along the reading scale. The principal utility of such a graph, however, will be in the criterion which it affords as to the comparative performance of instrument of diverse design or workmanship.

Lest it be felt that the importance of the hysteresis error due to bearing clearance and backlash has in the foregoing been over-estimated, the following should be given consideration. It may well be true that in some instruments, especially those of the least mechanical complexity, the error is small; in other cases it may have an appreciable value and yet be of minor importance as compared with the hysteresis due to imperfect elasticity of elastic resister elements and as compared with the drift or elastic after-effects, which also frequently accompany spring force-resisting elements. Nevertheless, in many instruments the backlash type of error arising in purely mechanistic sources is the one which governs the practicability of the desired accuracy and sensitivity. As examples, automatic or self-indicating weighing scales and balances, especially those using the principle of pendulum inclination, may again be called to mind. Another important class of instruments, in which the backlash effect is the limiting and preponderant factor, is that of length-measuring instruments commonly employed for measuring small differences of displacement. Examples of these are found in the dial-and-plunger instruments which use wheel or screw trains of high multiplication to convert rectilinear displacements at the receiving point into rotations of an indicator over a graduated dial. Were it not for the variance effects of mechanical hysteresis in these instruments they would obviously be applicable to the most refined length comparisons. In point of fact, one of the types most used, due to unavoidable deficiencies in the fit of the wheel-work spindles and meshing gears, shows variance differences amounting to several graduations, at a given displacement of the receiving point, the dial of this instrument being divided to $\frac{1}{10,000}$ in. of plunger displacement. This, then, is an example of an instrument in which variance errors have been the limiting factor; the extremely high magnification and considerable range of reading, with the necessarily large number of co-acting parts required thereby, makes their minimisation a very difficult matter.

Almost without exception, the complete calibration of measuring instruments of nearly every type, not excepting those using a liquid meniscus as indicating element, should include a determination of the variance characteristics. The magnitude of the variation shown in this determination will indicate whether or not it will be worth while to analyse the hysteresis effect into the factors which compose it, viz., the backlash effect, the imperfect elasticity effect, and the drift or elastic after effect.

(*c*) *Drift.*—Another phenomenon of considerable importance in some types of instrument is that of drift,

irreversibility in the thermal expansion of some materials, and effects more or less closely a function of time, such as temperature variations occasioned by changes in the state of stress, lag in the drainage of liquid from the walls of a tube, and the thermal lag noticeable in certain types of electrical instruments and resulting from temperature changes accompanying the flow of current.

* It may even be that a step-by-step motion of the linkwork and indicator, due to the discontinuities in the relative motion, referred to above, can be distinctly observed, typifying in a sense the point-by-point manifestation of passiveness in preventing continuous response of the instrument mechanism; and reflecting the discontinuity between the values of the static and kinetic friction of the linkwork.

which is a time effect characterised by a more or less gradual movement of the indicator, asymptotically to a definite reading, after all conditions external to the instrument have become constant. It would seem that very little of this effect can arise from causes originating in the kinematic relations of the linkwork; it must be due chiefly to elastic after-effect or the hysteresis of inelasticity in stressed portions of the measuring elements. If we accept, as applying to stresses other than torsional, the conclusions of J. J. Guest and F. C. Lea in their recent paper* on hysteresis phenomena, we may ascribe all such effects to conditions of actual overstrain in imperfectly elastic force-measuring or force-sustaining parts. An example is seen in the aneroid barometer, where drift takes place as a result of slow settling of the diaphragm or spring to a steady state of stress. It is quite reasonable to suppose that in corrugated diaphragms, such as are used for this purpose, zones of decided overstrain do exist.

3. Means for Reducing Variance.

(*a*) *Details of Design.*—Several possible remedies are to be considered for minimising the hysteresis loop of measuring instruments arising from the causes described. The most obvious one is, of course, to improve the fit of journals in their bearings to such an extent that the bearing clearance is negligible. This procedure is oft-times mechanically impracticable for several reasons. First, that when an ideally close fit is had, the journals and their bearings must have cross-sections which are perfectly circular, since otherwise any relative rotation would result in binding; second, slight differences in the temperature of the parts or in the condition of the

Fig.6.

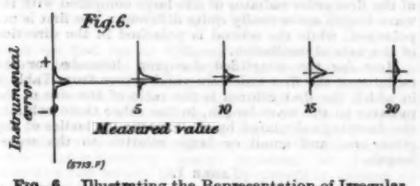


FIG. 6. Illustrating the Representation of Irregular Variance by Reference to a Family of Probability Curves Developed at Various Points along the Instrumental Scale.

lubricant, or the introduction of dust in the use of the instrument, would increase the friction to an amount fatal to proper operation. Perhaps the best type of bearing to reduce these difficulties is the conical pivot, consisting of two oppositely directed cones engaging in suitably supported conical hollows, both the cone and its mating depression being quite sharp, and suited to each other as to included angle. This requires that the conical depression shall include a somewhat larger angle than the cone, in order that complete contact occur only at a point or infinitesimal surface in the axis of rotation. This is the type of bearing commonly used for the balance wheels of alarm clocks and low-priced watches. While having relatively low friction and maintaining a practically invariable relation of bearing to journal, it cannot, of course, withstand any considerable load.

Another method, which looks very promising in the limited application it has had in weighing scales and a very few other measuring instruments, is the use of a flexible or ribbon-like elastic connector, secured to the conjoined members by means of clamps or equivalent device. With such a connector, the constancy of distance between centres of relative rotation for a given configuration of the system is assured in a practically perfect manner, neglecting temperature and similar effects which are common to all types of bearings. The only contribution of this type of connector to the total hysteresis of the instrument lies in its own elastic hysteresis, which should be very small indeed for very thin bands or ribbons of steel or similarly favourable material, operated as they commonly are, through but small or moderate arcs of motion.

Knife-edges in V-shaped bearings or single cone points and cups arranged as shown in Figs. 7 may be used if the shape and position of the bearing and edges are such as to insure the contact remaining always at the intended point. It is difficult to see, however, where this arrangement can offer any important advantage over the flexible connector just described, except in the case of precision instruments for use in the laboratory, where the most careful operation and handling can be assured.

The flexible connector has another important property which has been utilised to a considerable extent in the design of automatic scales, viz., that a correction of the motion of the parts to obtain a linear or uniform scale of graduations can readily be secured by arranging that one or both ends of the tape wind upon a cam of suitable contour, a feature whose importance will readily be appreciated. It does not seem that the use of the flexible connector in such instruments as pressure gauges (including aneroids), recording thermometers, hygrometers, tachometers, and the like, has been as extensive as the favourable properties of the device warrant, and a marked improvement in the constancy or reproducibility of reading of such instruments should be secured by employment of this arrangement. Critical examination of the usual pressure gauges and tachometers, as well as complex recording instruments generally, will convince one that the importance of special care in the design of the turning pairs in the linkwork has not been commonly appreciated, and it does not seem that the best practicable performance of such mechanisms has been approximated.

In connection with the pressure-measuring element familiar in the aneroid, an important development has been noted in certain recording instruments, and is now being manufactured for use in aviation instruments of the indicating type, its object being to eliminate gearing and jointed linkwork. Instead of the common diaphragm or monoplanar Bourdon tube of small movement, a helically-coiled Bourdon tube is used, connected at one end to the fixed frame of the instrument, and at the other, through a temperature compensator which need not be described, to the indicator spindle, which latter is concentric with the helix. As pressure is applied, the Bourdon tube tends to uncoil, and drives the coaxial pointer directly, without the need for gear or link trains of any kind. A considerable arc of pointer movement can easily be obtained in this way without complication, and it would seem, with very satisfactory reliability. The importance of improvement in this field is appreciated when it is known how extensively the compact and inexpensive pressure-diaphragm construction has recently been applied in the development of every variety of aviation instrument, in which use, of course, the direct pointer-reading type is to all intents and purposes a necessity as against the liquid-column manometer. The diaphragm capsule and the Bourdon tube are now employed in thermometers, air-speed indicators, altimeters, liquid-depth gauges, and in many other applications apart from the simple determination of static pressure.

(*b*) *Effects of Vibration.*—With the considerations developed in the foregoing in mind, it is easy to see how the effects of vibration treatment suitably applied to an instrument at the time of reading will tend to correct

Fig.7.

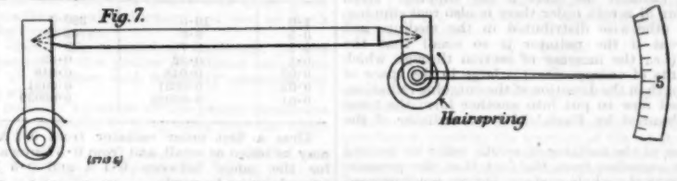


FIG. 7. A Simple Type of Connector having Low Frictional Resistance and Affording Satisfactory Constancy in Distance Relationships.

the errors introduced by friction and backlash. It is a well-known fact that with certain instruments, such as Bourdon tube or diaphragm pressure gauges, the reading tends to settle toward a more reliable and reproducible value if the instrument is tapped or jarred. The interaction of parts which brings this about will be perfectly in line with the facts developed above. Briefly the effect is of two related sorts: (1) The minimisation of static friction by the momentary disengagement or separation of co-acting bearings and journals, and (2) the opportunity which the same disengagement affords, for journals to settle to the "minimum" or base-point of contact in their bearings. On the basis of this reasoning it would seem that the best results from vibration treatment before a reading is taken will ensue when the vibration starts with a relatively large amplitude and decreases finally to practically zero amplitude, since the slight shifting about the optimum indication, due to the amplitude of the vibration itself, is thus eliminated. In brief, the effect of vibration is to permit the forces which tend toward a definite, unique, equilibrium point and are inherent within the instrument, to operate against the minimum possible resistances in moving the parts toward that equilibrium; in another sense, energy is applied from without the system to replace that unavoidably lost in the deficiencies of the mechanism. On this point an analogy with magnetic hysteresis exists. A substance is most accurately brought to a given state of magnetisation by subjecting it to a field whose intensity oscillates with decreasing amplitude about that (or corresponding) value of magnetisation.

A priori, it would seem that by vibration treatment judiciously applied at the time a reading is taken, errors of result due to the mechanical sources of variance can be almost completely eliminated.

4. Relation of Variance to Useful Sensitivity.

It is often found that particular measuring instruments are given a sensitivity far higher than warranted in the face of the error obtainable in reading and resulting from the variance present. Similarly, the graduation of instruments is often found to be far closer than the large amount of the variance justifies. Care should be taken in the design of measuring instruments that the units of graduation and the openness of the scale are not out of all proportion to the effective reproducibility of reading possible. For testing or laboratory instruments, the mean interval of graduation should not be less than five times the mean variance, since it is to be expected that observations will be noted accurately to one-fifth the smallest graduation or less. For commercial instruments the unit of graduation and the variance may be more nearly equal, say, in the ratio of 2 to 1.

It is obviously misleading and absurd to graduate a tachometer to a single mile per hour or revolution per minute when the reading at a given true speed may vary as much as 5 miles per hour or revolutions per minute. Such inconsistencies, however, are very frequent in practice, as is the related but less serious one of having a needlessly open scale on a very variant instrument.

Unnecessary time and care in taking readings are required when the sensitivity is ill-proportioned to the variance. Instruments are not common which possess such refinement of workmanship that the characteristics of successive hysteresis loops are uniform enough to permit of practical correction for the variance of observed readings. For these reasons the sensitivity may easily be disadvantageously high, in tending to induce an erroneous estimate of the precision of results, and if this mistake does not occur, in requiring careful investigation of the particular instrument involved to determine the portion of its maximum sensitivity which is really and practically available in service.

Other factors may well have a part in determining the sensitivity to be aimed at in a given instance, for example: In an equal arm balance it is preferable to use a relatively low inherent sensitivity, enhancing the visibility of changes in the deflection of the balance beam by the use of an optical lever, microscope and scale, or similar external means. In this particular case the advantages gained are (1) decreased period of oscillation, which reduces the drift and other errors flowing from the protraction of the observations over a long period of time; and (2) the greater ease of manipulation and control of a balance having low inherent sensitivity.

The factors of inaccuracy (or accuracy), sensitivity, specific set and variance may, as a convenient means of arriving at and expressing the "figure of merit" of an instrument, be referred to the total range of graduation instead of to the value of the measured quantity under observation, as presented in the definitions of the foregoing pages. For example, it will be of service to express the maximum set or maximum variance observed in the reading of an instrument in terms of its ratio to the total range of values represented in the graduation or use of the instrument, in order to arrive at a single significant number representing a measure of utility or merit of the instrument with regard to the particular property in question. In like manner the reciprocal of any of these quantities (that is, range of graduation divided by maximum set or maximum variance, &c.) may be similarly employed.

V. SUMMARY.

The terms accuracy, sensitiveness and variance in reference to the characteristics of a measuring instrument are most useful when quantitatively defined. In practice the first is best expressed in terms of its reciprocal, as the ratio of error, arising from whatever cause, observed in an indication of the instrument, divided by the true value of the quantity being measured, this value being the specific inaccuracy at that reading. This factor is useful in rating the performance of an instrument, while the absolute error observed is used as a means of correcting observations for use in calculation.

Sensitivity is the rate of displacement of the indicating element with respect to change of the measured quantity. The mode of expressing sensitivity should be definite and not dependent upon the observer's personal judgment; moreover, when possible it should be so chosen as to be independent of the accident of dimensions in the indicating element where such dimensions or the final magnification of indicator movement are within reasonable limits alterable at will.

The effect of passiveness or sluggishness in the action of instruments is to be clearly distinguished from insensitiveness. Emphasis is laid upon the fact that sensitivity cannot be determined by direct measurement unless friction and lost motion are sensibly eliminated or are negligible. The amount of the passiveness at any point of the instrumental scale is measured by the smallest alteration in the quantity to be measured which will produce any change whatever in the indication of the instrument. The relative sluggishness or passivity at any point is that change of value of the measured quantity which effects the first perceptible response in the indication of the instrument, divided by the initial value of the measured quantity.

The term variance is to express all changes of indication intrinsic within the instrument itself, and not *per se* indicative of change in the measured quantity. It is defined as the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, after a steady reading has been attained, the environment remaining unchanged. The specific variance or variancy is the ratio of the range of variation above defined divided by the value of the measured quantity itself.

Variance arises in three causes of mechanistic character: (1) Backlash, the operation of which in producing variance effects is fully discussed in the complete paper, and (2) friction, the primary manifestation of the latter being passiveness, discussed above. Moreover (3), in all instruments using any of the various forms of springs as the force-resisting or restoring element, variance arises in the imperfect elasticity of that spring; this source of instrumental hysteresis is a direct reflection of the hysteresis loop in the stress-strain relation of the material composing the spring. The variance, which embodies all of the foregoing sources of variation from unique reading for a given value of the quantity to be measured, represents the range of uncertainty of indication exclusive of the factor of drift, which, being a time effect, demands special consideration.

* J. J. Guest and F. C. Lea, "Torsional Hysteresis of Mild Steel," Proc. Royal Society, June 1, 1917.

The latter effect, however, is peculiar to instruments in which a considerable range of stress in the parts occurs during their operation, or in which the elastic properties of the elements of the mechanism are unfavourable. The set of an instrument is the amount by which the indicator fails to return to its initial position after a deflection has occurred. The relative or specific set is the ratio of this residual deflection divided by the deflection which occasioned it.

The errors manifested as variance are often of great importance and should be examined into before they are assumed to be negligible, as they occur in all types of instruments and often have the effect of delimiting the field of useful application of the instruments.

The variance of an instrument of good characteristics can be defined by reference to the hysteresis loop obtained through cyclic variation of the measured quantity, against the values of which quantity are plotted the corresponding readings (or errors) of the instrument. In other cases the variance can be expressed by reference to a family of probability curves giving the frequency of occurrence of each particular reading (or error) for a given value of the measured quantity (or, conversely, giving the frequency of particular deviations of the measured quantity for a given reading).

Calibration curves of typical instruments are presented to show the character of the hysteresis loops and the nature and amount of variance errors as actually determined.

Instrumental variance may be reduced by simple changes in details or simplification of design, the former relating especially to the points of jointure in the linkwork. Important factors in the design of such connections have failed of recognition in the development of many common instruments. Vibration of some kinds of instruments at the time the reading is taken will reduce the variance on account of its effect in minimising the static friction opposing the motion of the parts of the mechanism to the position of equilibrium.

The amount of variance determined for an instrument should establish the optimum sensitivity to be sought in its adjustment, and also, roughly, the scale interval. High sensitivity or needlessly minute graduation, when accompanied by high variancy, are likely to be both uneconomical and misleading. A working basis for determining the sensitiveness to be sought in the adjustment of the instrument, and the closeness of graduation can readily be established.

Industrial and Commercial Activity in Hong Kong.—The Colonial Report, No. 972, for Hong Kong, for the year 1917, states that in the preceding year, 1916, 54 vessels, of a total of 10,902 tons gross and 9,377 i.h.p., were built by 14 firms, whilst in 1917, 26 vessels were built, having a total of 24,092 gross tons and 15,507 i.h.p. The report adds that the Hong Kong and Whampoa Dock Company had several large vessels building which are not shown in the total. The business done in tin showed a considerable increase in comparison with 1916, the demand from Europe and America being much greater. Imports from Yunnan in 1917 amounted to about 11,000 tons, and from Kwangsi to about 200 tons, as against 3,000 tons and 1,000 tons respectively in 1916. During the year, about 200 tons were exported to Japan, 1,400 tons to Shanghai and other China coast ports, and 13,000 tons to Europe, Canada and the United States of America.

Giant Suns.—Discoursing upon "Giant Suns" and on giant and dwarf stars at the Royal Institution on January 31, Professor H. H. Turner, F.R.S., of Oxford, referred chiefly to recent work on the classification of star spectra, and the suggestions made for their explanation. Direct and photographic determinations of parallaxes had taught us much about the distances of stars, and the studies of double stars also about their masses. In brightness and masses two binaries of a star system mostly did not differ very much; yet Procyon was 26,000 times brighter than its dark companion and had only five times its mass; in Castor the relations were 2½ to 1 and 1 to 20 respectively, in Sirius 400 to 1 and 2½ to 1. The classification of star spectra aimed at connecting the spectrum with the temperature of the surface of the star (we knew nothing about the interior). The most systematic classification work was done by Miss A. Cannon, at Harvard. It was believed that the red M stars had a temperature of about 3,000 deg., and that the temperatures in K, G, A, B stars went up to 4,000 deg., 5,500 deg., 10,000 deg., and 20,000 deg., and even higher in O stars. Now W. W. Campbell had found in 1910 that the velocity of the oldest stars which were then believed to be the coolest was higher than that of young hot stars. But it was also observed that stars of the same spectroscopic class differed much in luminosity, and it seemed that there might be giants and dwarfs in each class. In 1913 H. N. Russell and Hertzsprung suggested that temperature was not an infallible criterion of age; the luminosity might first increase and then diminish again, and the same star would thus first ascend, and then descend in the scale of magnitude. Thus our sun (class G, absolute magnitude 5) was once of magnitude O, and would at that time have appeared to us to be of 10 times its present size. This view had been confirmed by W. S. Adams by the study of the relative fluctuations in intensity which certain lines showed in spectra of the same classes, and A. S. Eddington had quite recently shown how the temperature changes were to be understood. When the mass of a gas or stellar nebula contracted under the influence of gravity, the system grew hotter, until the radiation pressure of light set up an opposing repulsive force; on that view the effective temperatures of stars of different spectral types became possible.

SOUND FIELDS AND SOUND ANTENNAS.*

By W. Hahnemann and H. Hecht.

(Part II.)

In the first part of this investigation (*Phys. Zeitschrift*, vol. xvii, page 601, 1916) we gave a mathematical discussion of a radiator of zeroth order, which is in the form of a pulsating sphere, and we deduced some applications of practical utility. When we consider radiating bodies of higher orders, the most interesting are those of the first order. So we will now begin by giving the deduction of the formulæ for a radiator of the first order, following Rayleigh's method. As for radiators of higher orders, for practical applications we need only state that in general we can, by a simple system, replace these by bodies of the first order.

In the second section of this paper we will use the results already obtained for "zero radiators" to show by an example how certain radiators, to which exact mathematical calculation cannot be applied, can be treated with sufficient accuracy for practical purposes.

In our third section will be given experimental determinations of quantities of which the calculated values have also been deduced mathematically, thus checking and confirming the theoretical results.

§1. Theory of Radiator of the First Order.

In order to treat mathematically the radiators of the various orders, Rayleigh chooses the spherical form and expresses the velocity potential as a spherical harmonic. The radiator of the zeroth order is represented by a sphere, every part of whose surface is moving in the same phase and with the same amplitude. We call this a pulsating or breathing sphere. The radiator of the first order is represented by a sphere oscillating to and fro about a position of equilibrium. While with a radiator of zeroth order only a radial movement of the medium is possible, with a first order radiator there occurs also a tangential movement of the medium, which contributes nothing to the radiation. We will call this tangential movement the slipping of the medium. The slipping movement is only a to and fro displacement of masses not occasioning pressure and becoming acoustically effective, while the radial movement is the real motion giving pressure and radiation. How much of the total movement is slipping motion and how much is radiation motion depends on the ratio of the size of the radiator (of first order) to the wave-length; the smaller the radiator the more is the slipping. Even with radiators of zeroth order there is also real slipping, but this is otherwise distributed in the medium and becomes great if the radiator is so small that the divergence (*i.e.*, the increase of section through which equal amounts of energy enter) is large in the space of one wave-length in the direction of the outgoing radiation.

We proceed now to put into another form the force equations obtained by Rayleigh† for a radiator of the first order.

In the case of the radiator of zeroth order we derived the pressure equation from the fact that the pressure is constant over the whole surface, but we must proceed quite differently when we consider the radiator of the first order in which, as we pass from the poles to the equator, the pressure falls off from the maximum value down to zero, the oscillations being in the direction of the polar axis. We have then to integrate over the whole system.

As in Part I of our paper, we shall alter Rayleigh's symbolisation, writing w/a for κ, R for c, k for Σ, and α and β for p and q. The force equation then takes the form:

$$k = \frac{4\pi}{3} R^3 \rho a \frac{\partial i}{\partial t} + \frac{8\pi^2}{3} R^3 \rho n \beta i,$$

* Translation by Mr. Albert Campbell of a paper published in the *Physikalische Zeitschrift*, of June 15, 1917. The translation of the first part of this paper appeared on page 756 of our issue of December 27 last, and we reproduce from it a list of the symbols used by the authors. They are as follow:—

Nomenclature.

ξ = instantaneous value of the displacement.
A = maximum value of the displacement.
i = instantaneous value of the velocity.
I = maximum value of the velocity.
p = instantaneous value of the pressure.
P = maximum value of the pressure.
V_0 and P_0 = corresponding values of volume and pressure.
V = maximum value of change of volume.
ρ = density.
C = compressibility factor.
κ = ratio of specific heats.
a = velocity of propagation.
n = frequency (cycles per sec.).
$\omega = 2\pi n$.
λ = wave-length.
ϕ = phase angle between pressure and velocity.
r = distance from source of sound.
L = intensity of sound per unit area.
L_R = intensity of sound for surface of sphere.
M = oscillating mass per unit area.
M_R = oscillating mass for surface of sphere.
k = "Damping factor."
δ = damping (*i.e.*, log decrement).
w = electric resistance.
Π = electric self-inductance.
e = electric voltage.
j = electric current.
ϕ = velocity potential.
E = elasticity (modulus).

† Rayleigh, "Theory of Sound," vol. ii, §325, page 248, second edition.

where

$$\alpha = \frac{2 + (2\pi R/\lambda)^2}{4 + (2\pi R/\lambda)^4} \text{ and } \beta = \frac{(2\pi R/\lambda)^3}{4 + (2\pi R/\lambda)^4}.$$

Hence from the pressure equation, as before, we find the log decrement:

$$\delta = \frac{8\pi^2}{3} R^3 \rho n \beta/2 \times \frac{4\pi}{3} R^3 \rho a = \pi n \beta/a,$$

and the damping:

$$\partial = \pi \beta/a = \pi \frac{(2\pi R/\lambda)^3}{2 + (2\pi R/\lambda)^2}.$$

This expression for the damping takes a simple form when $(2\pi R/\lambda)^2$ is either small or large compared with 2. In these two limiting cases we have:

$$\partial_{R << \lambda} = 4\pi^4 (R/\lambda)^3$$

and

$$\partial_{R >> \lambda} = 2\pi^2 (R/\lambda).$$

The formula for a radiator small compared with the wave-length shows that the damping is proportional to λ^3, and thus gives an analogy with antennas for electromagnetic oscillations, which in our terminology must also be called radiators of the first order; but in the formula for the radiator large compared with the wave-length we recognise the damping formula for the zeroth radiator. This is easy to understand from the physical point of view, since for the first order bodies of at least the size of a half wave-length an appreciable slipping motion can scarcely occur, and it is the absence of such motion that is characteristic of zeroth order radiators. The sound fields of the zeroth radiator and of the first order radiator of size large compared with the wave-length are actually quite different: the first is not polarised, while the second is polarised in the direction of the axis of oscillation.

How far the simplified damping formulæ for the radiator of the first order are valid is seen from Table I, in which the first column is the ratio of the size of the radiator to the wave-length, in the other three columns the damping calculated by the formula for bodies of any given size and small or large relative to the wave-length.

Table I.

R/λ	$\frac{\pi (2\pi R/\lambda)^3}{1 + (2\pi R/\lambda)^2}$	$4\pi^4 (R/\lambda)^3$	$2\pi^2 R/\lambda$
1·0	10·0	390·0	20·0
0·5	3·0	49·0	10·0
0·2	1·7	3·1	4·0
0·1	0·32	0·39	2·0
0·05	0·048	0·049	1·0
0·02	0·0031	0·0031	0·4
0·01	0·00039	0·00039	0·2

Thus a first order radiator from 0·1 λ downwards may be taken as small, and from 0·5 λ upwards as large; for the range between 0·1 λ and 0·5 λ the exact formula must be used.

The last column also gives the radiation damping for a sphere of the same size oscillating cophasally at all points. We see from columns 2 and 4 that the ∂ of a body of first order, where $R/\lambda = 0{\cdot}02$, is only 1 per cent. different from that of an equal body of zeroth order.

The covibrating mass is found from the force equation; thus:

$$M = \frac{4\pi R^3 \rho}{3} \cdot \frac{2 + (2\pi R/\lambda)^2}{4 + (2\pi R/\lambda)^4}.$$

For the two extreme cases, as before:

$$M_{R << \lambda} = \frac{2\pi}{3} R^3 \rho$$

and

$$M_{R >> \lambda} = \frac{R \lambda^2 \rho}{3\pi}.$$

2. Theory of Membrane as Radiator of Zeroth Order.

Rayleigh ("Theory of Sound," vol. ii, §302, page 162, second edition) discusses the problem of the vibration of a stiff circular plate filling a circular hole in an infinite rigid flat plate.

The mathematical treatment is difficult and only gives simple results when the vibrating plate is small in relation to the wave-length.

We shall consider only the case most wanted in practice. Here the pressure and movement of the medium at the surface of the membrane are quasi-stationary, and the equations of pressure of the "piston membrane," as we shall call Rayleigh's plate, take the form:

$$p = \frac{8}{3\pi} R \rho \frac{\partial i}{\partial t} + \frac{a\rho}{2} \left(\frac{2\pi R}{\lambda}\right)^2 i.$$

[Here we have put $\frac{2\pi n}{a}$ for $\kappa = n/a$, ρ for σ and i for velocity ξ as used by Rayleigh.]

If F = area of radiating surface:

$$p = \frac{8}{3\pi\sqrt{\pi}} \sqrt{F} \rho \cdot \frac{\partial i}{\partial t} + 2\pi a \rho \frac{F}{\lambda^2} i.$$

Now let the plate radiate, not as hitherto in the half space bounded by a rigid plane, but in a medium infinitely extended in all directions; but with, as before, only one side of the plate meeting the medium, while the other side is covered with an enclosing cylinder, also small relatively to the wave-length. Then we can deduce the following consideration. The sound field, which a radiator of the zeroth order in a rigid partiti on

sets up in the half space, is equal to the sound held which two cophasal radiators of zeroth order of equal magnitude (*ceteris paribus*) sets up in the whole space, assuming that their distance apart is small compared with the wave-length. Hence the above pressure equation represents also the case of two radiators of magnitude F or of one radiator of magnitude 2 F in a free medium, since the assumption of their smallness relatively to the wave-length allows this simple addition.

Hence the pressure equation of a piston membrane of magnitude F in a free medium is :

$$p = \frac{8}{3\sqrt{2}\,\pi\sqrt{\pi}}\sqrt{F}\,\rho\frac{\partial \dot{s}}{\partial t} + \pi a \rho \frac{F}{\lambda^2}\dot{s}.$$

We shall compare with this the pressure equation of a spherical zero radiator of small dimensions relatively to the wave-length. From Part I of this paper we find for this special case :

$$p = R\rho\frac{\partial \dot{s}}{\partial t} + a\rho\left(\frac{2\pi R}{\lambda}\right)^2\dot{s}.$$

If we also introduce here, by the relation $F = 4\pi R^2$, the magnitude of the radiating surface, then the pressure equation of the spherical radiator is :

$$p = \frac{1}{2\sqrt{\pi}}\sqrt{F}\,\rho\frac{\partial \dot{s}}{\partial t} + \pi a \rho \frac{F}{\lambda^2}\dot{s}.$$

Thus the two equations are :

$$p_{\text{membrane}} = 0{\cdot}34\,\rho\sqrt{F}\frac{\partial \dot{s}}{\partial t} + \pi a\rho\frac{F}{\lambda^2}\dot{s}$$

$$p_{\text{sphere}} = 0{\cdot}28\,\rho\sqrt{F}\frac{\partial \dot{s}}{\partial t} + \pi a\rho\frac{F}{\lambda^2}\dot{s}.$$

Thus we find for so differently formed surfaces as a piston membrane and a sphere a very approximate agreement when the dimensions of the radiator are small compared with the wave-length. The actual radiation terms of the two equations are perfectly identical, and the terms arising from the co-vibrating mass differ from one another by only about 20 per cent. We can therefore solve approximately many problems of practical acoustics for which the velocity potential cannot be stated and of which rigorous mathematical treatment is very difficult, by the help of these two cases.

As example, let us take the case of a circular membrane rigidly clamped at the rim, which allows us to compare the results obtained from this theory with those given by rigorous mathematical deduction, and also to check them easily by experiment.

We shall choose the numerical coefficient in the pressure equation of the piston membrane according to the kind of curvature and boundary possessed by the radiating surface.

From the pressure equation of the piston membrane we find the force equation by integrating over the whole surface :

$$k = \frac{8}{3\sqrt{2}\,\pi\sqrt{\pi}}F\sqrt{F}\,\rho\frac{\partial \dot{s}}{\partial t} + \pi a\rho\left(\frac{F}{\lambda}\right)^2\dot{s},$$

where k is the total force caused by the motion of the medium and acting on the whole piston surface.

If we reintroduced the radius instead of the surface area, then :

$$k = \frac{8}{3\sqrt{2}}R^3\rho\frac{\partial \dot{s}}{\partial t} + \pi^3 a\rho R^2\left(\frac{R}{\lambda}\right)^2\dot{s}.$$

Let us now consider the piston membrane to be replaced by a circular membrane rigidly clamped at the rim. This membrane will correspond to the piston membrane when both have the same displacement volume. For the piston membrane this displacement (or deformation) volume is $\pi R^2 h$. To find it for the rim-clamped membrane we must know the curve form of the deformed membrane, and this form depends on the clamping, the nature of the action of the forces brought into play by the deformation, &c. We shall assume several probable curve forms, calculate the deformation volume for each, and then decide on a mean form factor with which we shall carry out the further calculations (of this example).

For this we take four curve forms, namely, a simple cone, an elastic curve of a beam clamped at both ends and loaded in the middle (see Hütte, vol. i, pages 566 and 568, 1911), a uniformly loaded beam, and a sine curve.

In Table II are given the deformation volume, the oscillation mass and the form factor, where :—

Deformation volume of a piston membrane of equal amplitude = (form factor)^2 × area.

Oscillation mass is the effective mass of the membrane taken at the centre of the membrane.

Effective mass = (mass factor)^2 × total mass of membrane.

(The mass factor will be used later on in determining the frequency of the diaphragm.)

It will be seen that all four curve forms are very similar in results. Let 0·6 be taken as mean form factor, near that of the most probable curve (No. 3). It will be shown later that the experiments justify this value.

From the force equation of the piston membrane we obtain that of the clamped membrane by putting 0·6 R in place of R, namely :

$$k = \frac{8\times 0{\cdot}6^3}{3\sqrt{2}}R^3\rho\frac{\partial \dot{s}}{\partial t} + \pi^3\times 0{\cdot}6^4\,a\rho R^2\left(\frac{R^2}{\lambda}\right)\dot{s}$$

or

$$k = 0{\cdot}4\,R^3\rho\frac{\partial \dot{s}}{\partial t} + 4\,a\rho R^2\left(\frac{R}{\lambda}\right)^2\dot{s}.$$

This expression for k represents the forces arising from the movement of the medium, where $\dot{s}$ is the velocity o

TABLE II.

—	Equation of Curve.	Deformation Volume. $= 2\pi\int y\,r\,dx$.	Form Factor.	Oscillation Mass. $2\pi d\rho^1\int\left(\frac{y}{h}\right)^2 x\,dx$.	Mass Factor.
Cone	$y = h\left(1 - \frac{x}{R}\right)$	$\frac{1}{3}h\pi R^2$	$\frac{1}{\sqrt{3}} \doteq 0{\cdot}58$	$\frac{1}{6}\rho^1 d\pi R^2$	$\frac{1}{\sqrt{6}} \doteq 0{\cdot}41$
Elastic curve of a beam clamped at both ends with force applied at mid-point.	$y = h\left[1 - 3\left(\frac{x}{R}\right)^2 + 2\left(\frac{x}{R}\right)^3\right]$	$0{\cdot}3\,h\pi R^2$	$\sqrt{0{\cdot}3} \doteq 0{\cdot}55$	$\frac{6}{35}\rho^1 d\pi R^2$	$\sqrt{\frac{6}{35}} \doteq 0{\cdot}41$
Elastic curve of uniformly loaded beam.	$y = h\left[1 - 2\left(\frac{x}{R}\right)^2 + \left(\frac{x}{R}\right)^4\right]$	$\frac{1}{3}h\pi R^2$	$\frac{1}{\sqrt{3}} \doteq 0{\cdot}58$	$\frac{1}{5}\rho^1 d\pi R^2$	$\frac{1}{\sqrt{5}} \doteq 0{\cdot}45$
Sine curve	$y = h\cos\frac{\pi x}{2R}$	$\left(\frac{\pi}{2} - 1\right)\frac{8}{\pi^2}h\pi R^2$ $= 0{\cdot}46\,h\pi R^2$	$\sqrt{0{\cdot}46} = 0{\cdot}68$	$\left(\frac{1}{2} - \frac{2}{\pi^2}\right)\rho^1 d\pi R^2$ $= 0{\cdot}30\,\rho^1 d\pi R^2$	$\sqrt{0{\cdot}30} \doteq 0{\cdot}55$

the centre of the membrane ; the first term is a wattless force, the other a watt-force. The quantity $0{\cdot}4\,R^3\rho$, when multiplied by $J^2/2$, gives the "idle vibrating" energy of the system, if J is the maximum value of $\dot{s}$; hence we call $0{\cdot}4\,R^3\rho$ the co-oscillating mass of the medium.

The quantity $4\,a\rho R^2\left(\frac{R}{\lambda}\right)^2$ multiplied by $(J/\sqrt{2})^2$, i.e., $J^2_{\text{eff.}}$, gives the energy given off by the system in the form of acoustic dynamical work ; hence we call $4\,a\rho R^2\left(\frac{R}{\lambda}\right)^2$ the acoustic radiation resistance.

In order to find the complete equation of oscillation of the membrane, we have to bring in in addition the forces pertaining to the membrane itself. The elasticity C of a membrane rigidly clamped (at the rim) does not depend only on the dimensions and material of the membrane, but also in great measure on the tensions and small deformations.

It is scarcely practicable to give an exact numerical value ; we may take, for example, that given by Hütte (page 621 (1), 1911) for the case of a plane membrane free from tension :

$$C = \frac{0{\cdot}22\,R^2}{d^3\,E},$$

where E is the elasticity and d the thickness of the membrane.

In order to calculate the oscillation mass of the membrane, namely, the fraction of the whole membrane mass to be taken as vibrating concentrated at its middle point, we must form the integral of the square of the amplitude ratio into the mass element. This calculation has already been carried out for four different curve forms (in Table II). As in the examination of the force equation, we decide again for the curve form of a uniformly loaded beam with both ends clamped, and choose as mass factor 0·45. Experiments described below will prove the correctness of this choice also.

Thus we first assume the oscillation mass (m) of the membrane to be :

$$m = (0{\cdot}45\,R)^2\,\pi\,d\,\rho^1,$$

where ρ^1 is the density of the material.

If s is the impressed force maintaining the oscillations of the membrane, we obtain the complete force equation :

$$s = (0{\cdot}4\,R^2\rho + 0{\cdot}2\,\pi\,R^2 d\,\rho^1)\frac{\partial \dot{s}}{\partial t} + 4\,a\rho R^2\left(\frac{R}{\lambda}\right)^2\dot{s} + \frac{d^3\,E}{0{\cdot}22\,R^2}\int\dot{s}\,dt.$$

From this equation we can find directly the quantities that interest us, such as the co-oscillating mass of the medium, the frequency and the damping. The co-oscillating mass of the medium is :

$$M = 0{\cdot}4\,R^2\rho,$$

the frequency (neglecting the effect of damping) :

$$n = \frac{1}{2\pi}\sqrt{\frac{d^3\,E}{0{\cdot}22\,R^2(0{\cdot}4\,R^3\rho + 0{\cdot}2\,\pi\,R^2 d\,\rho^1)}}$$

and the log decrement :

$$\delta = \zeta' n = \frac{4\,a\rho R^2(R/\lambda)^2}{2n\times 0{\cdot}4\,R^3\rho}\cdot\frac{M}{M+m} = 5\frac{R}{\lambda}\cdot\frac{M}{M+m}$$

If we can neglect the mass of the medium relatively to the mass of the membrane, as may generally be done for metal membranes in air, then the frequency :

$$n_1 = \frac{1}{2\pi}\sqrt{d^3\,E/0{\cdot}22\,R^2\times 0{\cdot}2\,\pi\,R^2 d\,\rho^1} = 0{\cdot}43\frac{d}{R^2}\sqrt{E/\rho^1}.$$

(Of course, this is only strictly true for vacuum.)

As we have already mentioned, this formula for obtaining the frequency of membranes in air is inexact and untrustworthy on account of the uncertainty of the assumed value of the elasticity. In practice we invert the procedure and always try to determine the frequency, in order to find the elasticity from it and the oscillation mass, which can be rigorously estimated.

The expression for the damping :

$$\delta = 5\frac{R}{\lambda}\cdot\frac{M}{M+m}$$

represents only the value of the radiation damping. It takes no account of internal or wasteful damping, or of useful damping produced by the brake effect of special additional arrangements such as microphones or telephones ; they would give, in the oscillation equation, an additional term of the form $w\,\dot{s}$, where w may be called the acoustic brake resistance.

If we consider again the case of a metal membrane in air, the radiation damping has the value :

$$\delta = 5\frac{R}{\lambda}\cdot\frac{M}{m},$$

or, substituting the values of M and m :

$$\delta = 5\frac{R}{\lambda}\cdot\frac{0{\cdot}4\,R^3\rho}{0{\cdot}2\,\pi\,R^2 d\,\rho^1} = 3{\cdot}2\frac{R^2}{d}\cdot\frac{1}{\lambda}\cdot\frac{\rho}{\rho^1}.$$

Since for this case the frequency is given by :

$$n = 0{\cdot}43\frac{d}{R^2}\sqrt{\frac{E}{\rho^1}},$$

by substitution of this value we have for the damping :

$$\delta = 3{\cdot}2\frac{0{\cdot}43\sqrt{E/\rho^1}}{n}\cdot\frac{1}{\lambda}\cdot\frac{\rho}{\rho^1} = 1{\cdot}4\frac{\rho}{a}\sqrt{\frac{E}{\rho^1}},$$

where a is the velocity of sound in air.

We thus obtain the very interesting result that, assuming the mass of the membrane to be large compared with the co-oscillating mass of the air, the radiation damping of membranes is independent of their size and acoustical pitch, and only depends on their material. The damping increases with the ratio of the elasticity to the density. In order to attain large damping we must therefore choose the material from this point of view.

If we insert the values for air :

$$a = 33{,}300\text{ cm./sec.}$$
$$\rho = 0{\cdot}0012,$$

the damping becomes :

$$\delta = 5\times 10^{-6}\sqrt{E/\rho^1}$$

For bronze membranes with :

$$E = 10^{12}\text{ dyne/sq. cm.}$$
$$\rho^1 = 8{\cdot}5$$

we have :

$$\rho = 0{\cdot}002.$$

The damping of membranes in air is accordingly very small in all cases. Since the wasteful damping by internal friction is of the same or greater amount, a determination of the damping in air would not be suitable for checking our damping formula.* We therefore choose water as medium, in which, as we shall see immediately, considerably greater damping is to be expected.

In order to investigate how the damping of a membrane in water depends on its magnitude, we have calculated the thickness d of a bronze membrane for various values of radius R for fixed density and giving a frequency of 1,000 cycles per second ; col. 3, Table III, gives the mass

TABLE III.

R.	d.	Oscillation Mass of Membrane.	Co-oscillating Mass of Water.	Membrane Mass / Water Mass.	δ.
1	0·0161	0·086	0·40	0·21	0·029
2	0·053	1·13	3·2	0·35	0·053
3	0·108	5·2	10·8	0·48	0·071
4	0·178	15·2	25·6	0·51	0·088
6	0·36	70·0	86·0	0·81	0·116
8	0·61	208·0	204·0	1·02	0·138
10	0·92	490·0	400·0	1·23	0·157
15	1·93	2,320·0	1,350·0	1·72	0·193
20	3·1	6,650·0	3,200·0	2·1	0·226

of the membrane, col. 4 the co-oscillating mass of the medium, column 5 the ratio of membrane mass to medium mass, and column 6 the damping δ. From this table it will be seen that the damping seems to approach limiting value. The reason for this is that, as the radius

* It is also for this reason that membrane transmitters for air can only be constructed with very small efficiency. Sirens are sound transmitters of greater intensity ; their radiation output can be calculated by the formula for zeroth radiators with slight transformation.

is increased, the membrane mass gradually becomes great relatively to the medium mass, and so the relations become the same as we have already shown to hold for air; in particular the damping then becomes only dependent on the material of the plate. In every case we see that the damping is greater than in air. For this reason, as we have already mentioned, we have carried out our experiments for the proof of the damping formula in water as medium.

As we have already shown, the formula for the radiation damping in water is:

$$\delta = 5\,\frac{R}{\lambda}\cdot\frac{M}{M+m}.$$

In order to avoid the uncertainty which, do what we will, remains in the calculation of the masses M and m, and which very often is increased by the arrangements for the measurement of the amplitude (telephone armature, &c.), we can replace the ratio of the masses by the ratio of the corresponding frequencies. If n_a and n_w are the frequencies in air and water, then:

$$\frac{m}{M+m} = \left(\frac{n_w}{n_a}\right)^2,$$

or

$$\delta = 5\,\frac{R}{\lambda}\left[1-\left(\frac{n_w}{n_a}\right)^2\right].$$

This is the most suitable form in which to express the damping for the purpose of checking it by actual observations.

Before we proceed, however, to check our theoretically deduced values by experiment, we will compare the value of the power indicated by a membrane, as deduced from the force equation and the form factor, with the value obtained by M. Wien by other direct methods.*

In the paper we have mentioned, Wien considers a membrane fixed in a rigid wall and set in motion ("excited") at its centre; he finds the energy A, which it sends out at a given distance three unit area in unit time, to be given by the formula:

$$A = \frac{(0.147)^2\, p_0\, k\, w^4\, a_0^2\, R^4}{2\, a^3\, r^2},$$

where a = velocity of sound.
r = distance from plate.
p_0 = air pressure.
k = ratio of specific heats.
a_0 = amplitude of middle point of plate.

(By a printer's error R^4 had been omitted in Wien's original paper.)

Since:

$$a = k\sqrt{p_0/\rho}$$

and

$$w\,a_0 = J,$$

the equation becomes:

$$A = \frac{(0.147)^2\,\rho\, w^2\, R^4\, J^2}{2\, a\, r^2}.$$

The whole of the power radiated by the sounding plate into half space is found, by multiplying this by $2\pi r^2$, to be

$$L = 4\pi^3 \times (0.147)^2\,\frac{\rho}{a}\cdot n^2\, R^4\, J^2$$

$$= 2.7\, a\,\rho\, R^2\,(R/\lambda)^2\, J^2.$$

The force equation of the membrane, which is the basis of Wien's mathematical investigation, can be found from the equation of the piston membrane by the introduction of the form factor 0·55, which is taken from Table II for a force applied at the mid-point. Thus:

$$k = \tfrac{1}{3}\times(0.55)^2\, R^3\,\rho\,\frac{\partial\, i}{\partial\, t} + 2\,\pi^3\,(0.55)^4\, a\,\rho\, R^2\left(\frac{R}{\lambda}\right)^2 i;$$

or

$$k = 0.44\, R^3\,\rho\,\frac{\partial\, i}{\partial\, t} + 5.6\, a\,\rho\, R^2\left(\frac{R}{\lambda}\right)^2 i;$$

The power radiated is found by multiplying the radiation resistance by $(I/\sqrt{2})^2$:

$$L = 2.8\, a\,\rho\, R^2\left(\frac{R}{\lambda}\right)^2 J^2,$$

which is in good agreement with Wien's value given above.

§3. Experimental Measurements on Membranes

1. *Co-oscillating Mass of Medium.*—Since the co-oscillating medium mass in air is small compared to the membrane mass, we chose water as the medium for the experimental verification of our theoretically-deduced formula. The co-oscillating mass in water was experimentally determined with a number of membranes of different radii and thicknesses and also different frequencies, and then in air the right amount of mass was fixed to the mid-point of the membrane to bring the pitch back to what it had been in water.

In Table IV the results obtained are compared with the calculated values.

Assuming that M is proportional to some power of the membrane radius, i.e., that $M = x\,R^y$, we find as the mean of all the observations:

$$x = 0\cdot53$$
$$y = 2\cdot7$$

as against the theoretical values:

$$x = 0\cdot4$$
$$y = 3\cdot0$$

As the observations were by no means precision measurements, but merely "technical" determinations, the agreement with the theory is satisfactory.

* M. Wien, "Pflügeos Archiv für die ges. Physiologie," vol. xcvii, page 1 (1903).

Table IV.

R cm.	n_w	n_a	M Obsd.	M Calcd.	M.Cal−M.Obs / M.Cal.
2·1	2,140	3,120	4·5	3·9	− 0·15
2·1	1,465	2,240	3·8	3·9	+ 0·03
2·1	1,160	1,820	5·0	3·9	− 0·28
2·1	940	1,410	3·2	3·9	+ 0·18
2·5	490	670	5·5	6·3	+ 0·13
4·0	1,240	1,880	23·0	22·0	− 0·05
5·6	1,200	1,800	60·0	56·0	− 0·07

2. *Oscillation Masses of Membranes.*—Added weights were put on three bronze membranes in air, and the frequency was determined after each addition.

If n_0 = frequency without load.
n_b = frequency when loaded.
m = oscillation mass of membrane.
and z = added mass,
then

$$\left(\frac{n_0}{n_b}\right)^2 = \frac{m+z}{m}$$

or

$$m = z/\left[\left(\frac{n_0}{n_b}\right)^2 - 1\right].$$

We chose this method because the uncertainty in the calculation and determination of the elasticity (as set forth above) forbade us to use the direct method of calculating the oscillation mass from the frequency of the unloaded membrane.

The results of the experiments are given in Table V.

Table V.

Radius, Cm.	Thickness, Cm.	Density.	z.	n. ∼ /sec.	m.	m (mean).
2·1	0·06	8·5	0	1,840	—	
			2	1,200	1·48	
			4	960	1·50	
						1·49
5·1	0·3	8·5	0	1,760	—	
			11	1,560	41·0	
			30	1,350	43·0	
			56	1,145	41·5	
			74	1,045	40·5	
			109	920	41·0	
			145	840	42·5	
						41·6
5·6	0·3	8·5	0·0	1,810	—	
			2·5	1,765	50·0	
			5·0	1,710	41·5	
			7·5	1,670	44·0	
			10·0	1,640	45·5	
			15·0	1,585	50·0	
			20·0	1,530	50·0	
						48·5

To find the mass factor f for the three membranes we have the three equations:

$$1\cdot49 = \pi\times(2.1)^2\times0.06\times8.5\,f^2$$
$$41\cdot6 = \pi\times(5.1)^2\times0.30\times8.5\,f^2$$
$$48\cdot5 = \pi\times(5.6)^2\times0.30\times8.5\,f^2$$

and hence the three values are:

$$f = 0\cdot46,\ 0\cdot45 \text{ and } 0\cdot44,$$

giving a mean value 0·45, which is identical with the value calculated for the curve form of an end-clamped uniformly loaded beam.

The frequencies of these three membranes differ from the calculated values for reasons some of which we have already mentioned (internal strains, mode of clamping, assumed elasticity, &c.). If for bronze, we take:

$$E = 10^{12}\ \text{dyne/sq. cm.}$$

and

$$\rho^1 = 8\cdot5$$

then

$$n_{\text{bronze}} = 150\times10^5\cdot\frac{d}{R^2}.$$

In the following Table VI the observed and calculated values are compared.

Table VI.

n Obsd.	n Calcd.	n Calcd./n Obsd.
1,840	2,050	1·11
1,760	1,730	0·98
1,810	1,430	0·79

3. *Measurement of Damping.*—For the determination of the radiation damping the same three bronze diaphragms were used. A small iron armature was fixed to the mid-point of the diaphragm, and a telephone magnet was fixed to the rim which, relatively, remains at rest. The voltage induced in the coils of the telephone magnet by the vibrations of the diaphragm was measured by means of a crystal rectifier* and a galvanometer.

* The rectifier was of silver-molybdenite, known in radio telegraphy by the name of Hornemann detector. It was not adjusted to its maximum sensitivity, and thus for months it kept constant to about 10 per cent. The sensitivity of this measuring arrangement was not determined absolutely, but by comparison with highly sensitive telephones was found to be of the orher of $\frac{1}{10}$th to $\frac{1}{15}$th of their sensitiveness.

We convinced ourselves of the constancy of the rectifier and of the proportionality of the deflection to the square of the voltage by means of frequently repeated tests with shunted voltage (from an alternator) which was directly measured by a voltmeter.

The diaphragms were placed in air and in open water in the sound field of an acoustic transmitter, which was excited by constant force at various frequencies.

Its natural pitch lay so far above the highest frequency used, that the effect of its own resonance did not require to be taken into account. The resonance curves obtained were used for the determination of the decrement from about 0·8 to 0·2 of the maximum deflection, and gave values in good agreement among themselves. The results are given in Table 7.

Table VII.

Radius. cm.	Thickness, Cm.	$n_{air.}$ ∼ /sec.	$n_{water.}$	$\delta_{air.}$	$\delta_{water.}$
2·1	0·06	1,312	1,000	0·009	0·050
2·1	0·065	1,542	1,170	0·011	0·053
3·3	0·13	1,750	1,137	0·032	0·113

We should mention that for the first two diaphragms the damping in air was measured with their natural "air tuning," but for the third the measurements in air were made with the "water tuning" for which an added weight was used to bring the pitch down to that given in water. This had to be done, as its damping was strongly influenced by co-oscillations of internal parts. This procedure is distinctly to be preferred to that used with the other two diaphragms, since we should independently presuppose, as was found to be the case here, that there are no disturbing resonances in the range of frequency dealt with.

From the observed values of the damping in air and water we find the radiation damping in water as follows. The damping measured in air consists of three parts due to radiation in the air, dynamical hysterisis (internal waste) and magneto-electric effects. Thus, if we first subtract from the decrement measured in air the calculated amount due to radiation, namely, 0·002,* we obtain the amount of the electromagnetic and dynamical hysteresis damping for air tuning.

In order to correct this amount for the increased oscillation mass when in water we must multiply it by the square of the ratio of the frequencies in water and air. Subtracting the result from the observed value of the water damping, we obtain the radiation damping in water.

Table VIII gives a comparison of the values thus deduced from the observations with the values calculated by the formula:

$$\delta = 5\,\frac{R}{\lambda}\left[1-\left(\frac{n_{\text{water}}}{n_{\text{air}}}\right)^2\right].$$

Table VIII.

R Cm.	δ Obsd.	δ Calcd.	Obsd.—Calcd. Percentage difference.
2·1	0·031	0·031	0
2·1	0·041	0·036	+ 14
3·3	0·083	0·076	+ 9

The mean difference (8 per cent.) may be taken as a good proof of the mathematical theory. As the differences are positive, it is possible that other damping effects (*e.g.*, due to the friction of the surface of the diaphragm with the water) should have been taken into account.

* This is allowable since the calculated air radiation damping is only a small percentage correction on the observed water radiation damping.

Japanese Commercial Mission.—Mr. Yamashina, a former member of the Lower House of the Japanese Diet, and accredited representative of the Tokyo Chamber of Commerce, is in London. He has had conferences with the London Chamber of Commerce and with the president of the Associated Chambers of Commerce of the United Kingdom, and has discussed with them the prospects of the development of the trade of Great Britain with Japan. The interviews were entirely satisfactory, particularly as regards the desirability of closer relationship between the Chambers of Commerce of the two countries. Mr. Yamashina intends to leave London next Tuesday for France, Italy, Switzerland and Holland, with a view to promoting closer commercial relations between Japan and those countries. He will return here by April, and will then proceed to South America, *via* Liverpool.

Shipbuilding in Shanghai.—There are immediate prospects of something like 25 ships being built in Shanghai in the immediate future, says *The London and China Telegraph*. Contracts for all of these have not yet been signed, but the contemplated activities of yards in Shanghai justify such an estimate. The matter is of singular importance to this port, as it serves to show what are exactly its capabilities as a shipbuilding centre. The greater portion of the work must, of course, be looked upon as closely connected with the war. Consequently, it is not a true indication of what Shanghai has to expect when normal conditions again prevail. But the facts obtained during inquiry by a *North China Daily News* representative lend some support to the belief that work done upon correct lines might well lead to the establishment of a very considerable shipbuilding industry along the banks of the Huangpu.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

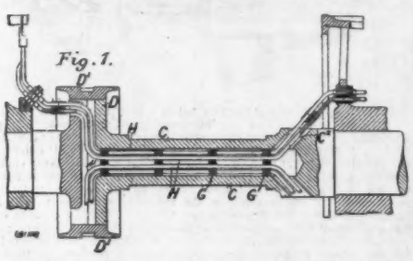
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

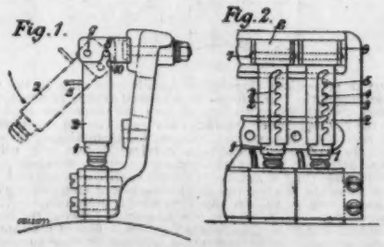
ELECTRICAL APPARATUS.

121,170. Bruce Peebles and Company, Limited, East Pilton, Edinburgh, and H. E. Webb, London. Dynamo Electric Machines. (7 *Figs.*) December 3, 1917.—This invention relates to such dynamo electric machines as comprise two axially-separated rotors or armatures mechanically connected by a shaft journalled at a point between the rotors or armatures in a fixed bearing and between which rotors or armatures electrical connecting conductors have to be carried through the shaft. According to the present invention, the bore of the shaft C is fitted with a series of suitably-spaced solid or other suitable insulators G, perforated with a series of symmetrically-disposed holes through which solid or stranded bar conductors H are carried; said conductors passing out radially at the ends of the shaft and being provided with end connectors by means of which they are mechanically and electrically connected to the respective rotor or armature windings. In the preferred form, the intervening length of shaft C and the bar or stranded conductors H rigidly held in place therein by the solid or other suitable insulators G, are constructed separately from the rotors



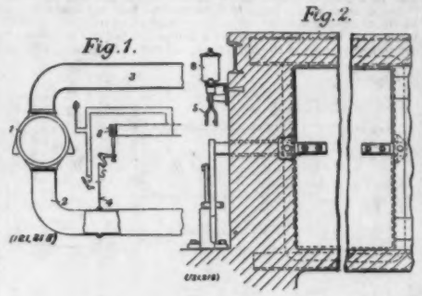
or armatures A, B, to be connected, the shaft C being provided with half-couplings D, D1 at the ends, and the said half-couplings being provided with radial channels through which the conductors pass out from the bore of the shaft, so that the arrangement forms a self-contained structure adapted to mechanically and electrically connect the rotors or armatures together and to provide a journal for the intermediate bearing. The half-couplings on the respective rotors or armatures are so constructed that the conductors pass through them axially at some distance from the centres; the conductors are, of course, spaced symmetrically circumferentially and the ends are provided with sweating connectors to take the connections to the rotor or armature windings. In a modification, the shaft C is made integral with one of the rotor or armature shafts, and the end is fitted with a half-coupling through which the conductors pass out as described, the other end of the said conductors passing out through obliquely or radially-arranged passage ways C2 in the wall of the shaft; the arrangement otherwise is as described. (*Accepted December* 18, 1918.)

121,217. The Phœnix Dynamo Manufacturing Company, Limited, Bradford, and A. H. Bennett, Shipley. Brush-Holder. (3 *Figs.*) January 26, 1918.—The present invention relates to brush-holders in which each brush as it wears away is fed forward by a plunger controlled by an internal spring enclosed in an outer tube with a vertical slot and offset notches co-acting with a pin carried on a plug behind the spring for the adjustment of the spring pressure on the plunger. According to the present invention, the headpiece carrying the tube containing the spring pressure plunger is mounted in such a manner as to make the said tube and plunger capable of being moved widely clear of the brush for renewals or inspections, while provision is made for maintaining the tube and plunger in a radial position when in use. 1 indicates the plunger controlled by internal spring pressure



mounted in an outer tube 2 with a vertical slot 3 and also offset notches 4 co-acting with a pin 5 for the adjustment of the pressure behind the plunger 1. Each outer tube, with its plunger, is set into a headpiece 6 fitted with two pins 7 and 8, set off the centre of the tube 2 on opposite sides, as shown in Fig. 1, which centre also corresponds with the centre of the pressure feed. The headpiece 6 is mounted in the jaws of the bracket 9, the pin 7 passing through the jaws of the bracket and acting as a pivot whilst the second pin 8, although passing through the thickness of the jaws, owing to the latter being slotted at 10, is free to move clear of the bracket when the pin 7 is used as the pivot. In Fig. 1, the movement of the pressure plunger 1 and its outer tube 2, when swung forward for the renewal or inspection of the brushes, is shown in dotted lines, the pin 7 acting as the pivot, while the pin 8 leaves the slots 10 in the bracket 9. When the plunger is again set radially, the pressure on the brushes, and the fact of the pins being set off the centre of pressure, holds the pin 8 in the bottom of the slot 10 and maintains the tube and plunger in a radial position. (*Accepted December* 18, 1918.)

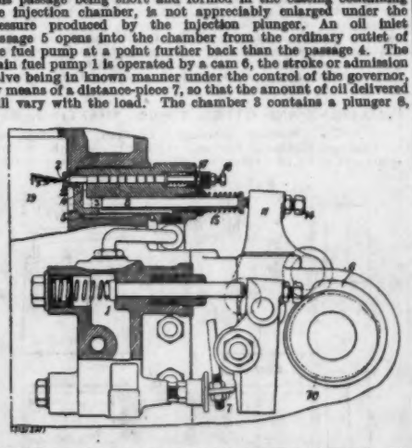
121,218. G. A. Jublin, Sale, and J. S. Peck, Altrincham. Dynamo Electric Machines. (3 *Figs.*) January 29, 1918.—This invention relates to dynamo electric machines of the kind in which air is supplied through a duct for the purpose of ventilating and cooling the windings when the machine is in operation. According to the invention, a valve is provided in the air duct, which is automatically closed when the machine is rendered inoperative due to a breakdown in its windings. A dynamo electric machine 1 is supplied through a duct with air which, after passing through the machine, is exhausted through an outlet duct 3. In the inlet duct 2 is provided a sliding damper 4, which can be held in its raised position by means of a pivoted trigger 5. A tail of the trigger is adapted to be raised so as to cause the damper to be released by means of a solenoid 8, which acts upon a magnetic core provided with an extension which engages the tail when the solenoid 8 is energised. The solenoid is connected in the circuit of a suitable source of energy



in such a manner that when a breakdown in the machine occurs, the operation of the protective gear, such as the well-known "Merz-Price" protective gear, which causes the disconnection of the machine from the circuit, will at the same time cause the solenoid to be energised, thereby operating the trigger to release the damper, which falls by its own weight and cuts off the supply of air through the duct 2. The solenoid circuit may be provided with a manually-operated switch, through which it may be energised from a suitable source at any time it is desired to close the damper, or it may be arranged in connection with any device for cutting off the excitation from the machine which may be provided, so that when this device operates due to a fault in the generator windings, the solenoid is energised and the damper released. A convenient way of arranging this is to connect the solenoid in series or parallel with the trip coil of the field circuit-breaking device, or it may be connected in series or parallel with the discharge resistance provided with any such field circuit-breaking device. (*Accepted December* 18, 1918.)

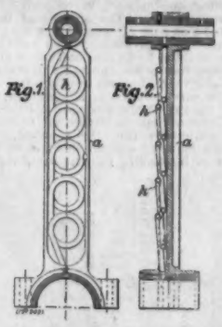
GAS ENGINES, PRODUCERS, AND HOLDERS, &c.

121,241. H. N. Bickerton, Ashton-under-Lyne, and A. B. Balmford, Ashton-under-Lyne. Oil Engines (1 *Fig.*) March 21, 1918.—The invention relates to engines of the semi-Diesel type. The invention consists in providing between the main fuel pump and the jet, an injection plunger which is positively operated, the oil passage from the plunger cylinder being of such a nature that it does not appreciably expand under the pressure produced. Between the usual fuel pump 1 and injection passage is provided a chamber 3, whose front end communicates with the injection orifice by a passage 4. This passage being short and formed in the casting containing the injection chamber, is not appreciably enlarged under the pressure produced by the injection plunger. An oil inlet passage 5 opens into the chamber from the ordinary outlet of the fuel pump at a point further back than the passage 4. The main fuel pump 1 is operated by a cam 6, the stroke or admission valve being in known manner under the control of the governor, by means of a distance-piece 7, so that the amount of oil delivered will vary with the load. The chamber 3 contains a plunger 8,



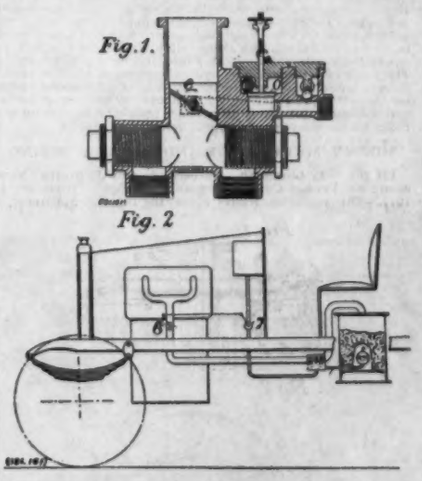
which is operated by a cam 10 acting through a lever 11. The normal position of the plunger 8 is adjustable by means of a set screw 14, and it is maintained in contact with this set screw by a spring 15. The injection orifice 2 is closed by a valve 16 maintained against its seating by means of the spring 17, and having a lift determined by the position of a set screw 18. The operation of the device is as follows: Oil is delivered by the main fuel pump 1 to the chamber 3. The plunger 8 then moves forward, its operating cam 10 being so placed with relation to the cam 6 that motion of the plunger 8 does not take place until the fuel pump 1 has delivered oil to the chamber 3. The oil from the chamber 3 is thus forced through the passage 4 under sufficient pressure to lift the valve 16, whereupon the fuel is injected from the orifice 2 into the main engine cylinder 19. Immediately the requisite amount of fuel determined by the travel of the plunger 8 has been injected through the orifice 2, the valve 16 closes so that spilling of oil into the engine cylinder cannot take place, and further, oil around the valve 16 and in the passage 4 is drawn back owing to the backward motion of the plunger 8. (*Accepted December* 18, 1918.)

121,243. F. W. Lanchester, London. High-Speed Reciprocating Engines. (2 *Figs.*) March 26, 1918.—The invention relates to the lubrication of high-speed reciprocating engines. The invention consists, in brief, in arranging, attached to or forming part of the connecting rod *a*, a conduit A of looped form, adapted to lift or convey the oil by dynamic action, from the crank-pin bearing to the gudgeon-pin bearing, by virtue of the motion of the connecting rod aforesaid. In one mode of carrying the invention into effect, an oil pipe A is bent into a series of loops, such as may be obtained by winding the tube on a mandril in the form of a spiral spring, and then spreading it out by diagonal pressure combined with tension on the two ends. Alternatively, the form required can be obtained by arranging a number of cheese-shaped studs in a row and winding the tube once round each stud in turn, the direction of wind being always the same, that is to say either uniformly clockwise or counter clockwise. The lubrication tube so formed is laid in a recess milled in one or other of the flanks of the connecting rod. The section of rod employed may be as commonly used in high-speed engines, namely, that of the ordinary rolled joist or "I" beam.



It will be understood that the axis of the loops is arranged parallel to the axes of the crank-pin and gudgeon-pin. The crank-pin is fed with a copious supply of lubricant, a certain amount of which finds its way into the orifice of the looped tube aforesaid. As the connecting rod swings, the oil thus entering the lubrication tube finds itself thrown round the loops in succession, and so is dynamically pumped from one end of the rod to the other. From the delivery end of the lubrication tube, passages and channels are provided to the gudgeon-pin bearing surfaces and, where required, to the slipper block surface or to the piston itself, and thereby adequate lubrication is secured. The looping of the tube requires to be in the right direction to accord with the direction of rotation. When the invention is applied to reversible engines, two pipes are fitted, arranged of opposite hand, so that which ever way the engine runs one or the other will serve. In this case, the channels to which the lubricant is delivered by the two alternative pipes are arranged as separate as is conveniently possible, so that the oil delivered by the one pipe cannot readily find its way back by the other. (*Accepted December* 18, 1918.)

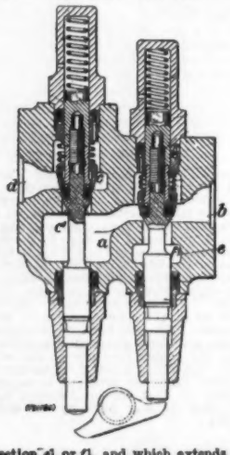
121,161. H. W. Bamber, London. Producer-Gas Plants. (4 *Figs.*) November 20, 1917.—The object of this invention is to provide a device by means of which the amount of water passing into the furnace of a gas producer is correctly regulated in accordance with the requirements of the said producer at any given moment. To effect this object, the valve *e* controlling the egress of gas from the producer is interconnected with a valve *o* controlling the supply of water to the furnace of the producer in such a manner that the amount of water allowed to pass to the furnace of the producer is directly proportionate to the amount of gas passing from the producer through the egress valve *e* at any given moment: When the producer is used to drive an internal-combustion engine directly, that is to say,



without the interposition of a gasholder, the throttle valve 6 of the internal-combustion engine may be interconnected with the valve 7 controlling the water supply, and therefore the engine throttle valve may take the place of the before-mentioned egress valve for the purpose of this device. Such apparatus is particularly useful in connection with motor-driven vehicles wherein producer gas is employed as the fuel for the internal-combustion engine, and the water supply to the producer or generator may be delivered thereto by means of a pump, under pressure, or by means of an elevated storage tank with a float chamber (similar to that employed in connection with the well-known hydrocarbon carburettor) interposed between the storage tank and the conduit leading to the nozzle within the generator wherein the water is to be supplied. (*Accepted December* 18, 1918.)

HYDRAULIC MACHINERY.

121,186. Davy Brothers, Limited, Sheffield, and C. A. Mills, Sheffield. Hydraulic Valves. (1 *Fig.*) December 6, 1917.—This invention relates to hydraulic piston valves. The two piston valves (that on the left is the inlet valve and that on the right the exhaust valve) are arranged side by side with their axes vertical, within a single casing having a central chamber *a* through which both valve spindles pass, and which is in open communication with a lateral branch *b* connected with the press cylinder (not shown). Above the chamber *a* is a port *c* in open communication with a second lateral branch *d* connected with the source (not shown) of hydraulic pressure; the port *c* is adapted to be put in communication with the chamber *a* by a vertical bore *c*1, through which passes the inlet valve spindle. Beneath the chamber *a* is a passage *e* in open communication with a third lateral branch (not shown) connected with the exhaust; this exhaust passage *e* is adapted to be put in communication by a vertical bore *f*1, through which passes the exhaust valve spindle, with that portion *f* of the chamber *a*, which immediately surrounds said spindle, and which thus constitutes in effect the exhaust valve port. The two valves are similar in construction. The opening of the valves alternatively is effected by a cam *g*. The sliding cup leather *k* in each valve is of U-shape in cross-section. The external diameter of each leather *k* is adapted to fit that section *c*1 or *f*1 of the bore wherein the leather rests when the valve is closed, as shown in the case of the inlet valve, but out of which the leather is raised entirely when the valve is opened, as shown in the case of the exhaust valve; the lips of the U-shaped leather being directed upwards in each case so that the leather will be distended radially by hydraulic pressure when the valve is closed. Each leather *k* is provided with a movable annular shield *o*, which, throughout the greater part of its length, has the same internal diameter



as the bore section *c*1 or *f*1, and which extends upwards across the port *c* or *f* into a chamber *o*1 surrounding the sleeve *m*1. Normally (*i.e.*, so long as the valve is closed) the shield *o* is held down by a spring *r* so that its flat annular lower end rests in contact with the level surface surrounding the upper orifice of the bore section *c*1 or *f*1, the shield *o* then constituting virtually an upward continuation of said bore section; but when the spind *e h* has been raised sufficiently to carry the leather *k* upwards wholly within the shield *o*, a shoulder at the lower end of the sleeve *m*1 engages an internal flange on the shield and causes the latter, during the remainder of the upward movement of the spindle *h*, to rise as one with the spindle and leather, thus opening the port *c* or *f* to the bore section *c*1 or *f*1. On the valve spindle *h* being allowed to descend under the stress of the spring *j*, the shield *o* is carried downwards by the spring *r* until it comes to rest against the surface surrounding the upper orifice of the bore section *c*1 or *f*1, after which the spindle *h* in its further descent to normal position carries along with it the leather *k*, which thus passes from within the shield *o* into the bore section *c*1 or *f*1. The leather *k* is distended by hydraulic pressure, which is allowed to gain access to its inner surface by way of notches (not shown) on the outer periphery of the shoulder on the sleeve *m*1 and corresponding notches on the inner periphery of the internal flange on the sleeve *o*. (*Accepted December* 18, 1918.)

MINING, METALLURGY AND METAL WORKING.

121,201. T. Lumsden, Gateshead, and J. Smith, Newcastle-on-Tyne. Casting Ingots. (3 *Figs.*) December 17, 1917.—This invention relates to casting ingots. Apparatus, in

Fig.1.

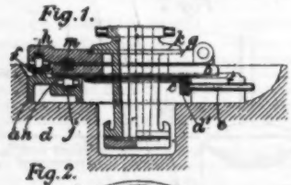
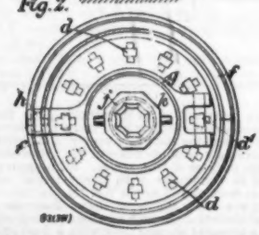


Fig.2.



accordance with this invention, comprises a mould supported in a collar pivoted to a table which is carried on rollers, and is adapted to be rotated by a circular rack and pinion or by any other convenient manner. On the underside of the collar is a roller adapted to bear on a stepped cam, the arrangement being such that as the table is rotated, the collar carrying the ingot is tilted a very small amount once in every revolution, or periodically and allowed to come back to the vertical position with a shock. Buffers may be provided between the collar and the table to take the shock of the jar if desired. On the bedplate *a* of the machine is mounted a table *b* provided with a circular rack *c* adapted to be supported by rollers *d* and to be driven by a bevel pinion *d*1 on the shaft *e*. The bedplate *a* is provided with a stepped cam face *f*. Pivotally mounted on a table *b* is a collar *g* provided with a roller *h* adapted to run on the cam face. The ingot mould *j* is provided with a flange *k* adapted to rest on the collar *g*. Buffers *m*, *m* are provided on the collar and table. In use, as the table is rotated, the mould is given a jar on each revolution as the roller *h* passes over the step of the cam. (*Accepted December* 18, 1918.)

121,213. J. Tylor and Sons, Limited, London, H. T. White, London, J. Gaunt, East Finchley, London, and D. Brookfield, Holloway, London. Smelting Furnaces. (4 *Figs.*) January 14, 1918.—This invention relates to smelting furnaces provided with a metal container or preheater that forms a closure to the furnace proper. Between the two furnaces, *a*, *a*1, and in direct communication therewith, is a chamber *b* that forms a connecting conduit between the two outlets *k* for the products of combustion coming through the preheaters *i* of the furnaces. This chamber forms a receptacle for the ingots which are to form a part of the next charge of either furnace. Adjacent

Fig.1.

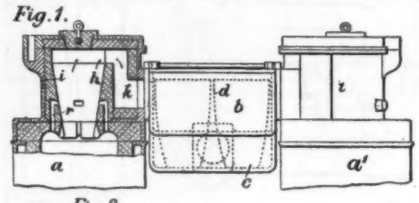


Fig.2

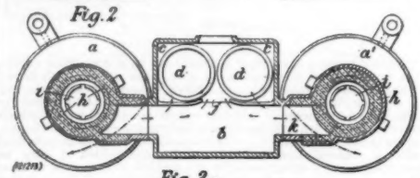
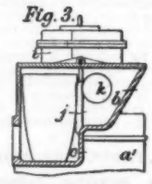


Fig.3.



to this conduit is provided a second chamber *c* to receive the crucibles *d* that are to be subsequently used in the furnaces, provision being made for the conveyance of the products of combustion from the metal heating chamber into the crucible chamber by the communicating opening *j*. With a view to facilitating the travel of the products of combustion or increasing the length of flame delivered into the metal heating chamber *b*, vertically disposed holes *r* are provided within the refractory lining *h*; these holes are open to the top of the furnace and convey the hot gases direct therefrom and deliver them more or less near to the top of the preheater *i* of the furnace without having to pass through the contents of the container. Obviously, the two furnaces *a* and *a*1 must be so placed with regard to the metal heating chamber *b* that when the preheater is in its normal position practically a close joint is formed therewith, as shown, to prevent the escape of the products of combustion. (*Accepted December* 18, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

121,148. William Asquith, Limited, Halifax, and G. Feather, Halifax. Lathes. (4 *Figs.*) November 2, 1917.—According to this invention, the carriage A extends over a

Fig.1.

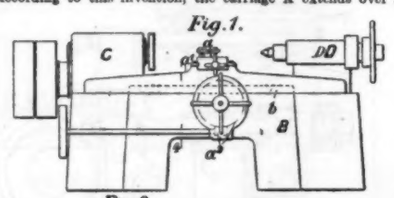


Fig.2.

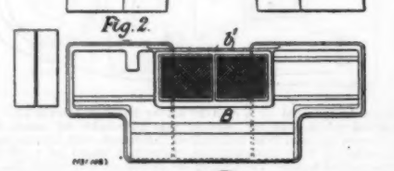
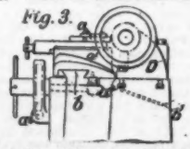


Fig.3.

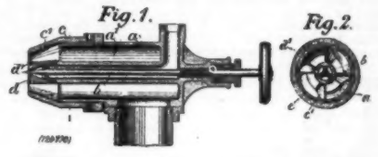


sufficient portion of the cutting way of the bed B on which it slides to prevent access of cuttings to the latter or to mechanism connected therewith in any position of the carriage, and the tool *a* is mounted approximately midway between the ends of the carriage to distribute the strain equally along same and prevent any canting action. The bed is formed with a narrow guideway *b* (preferably raised) for the carriage to reduce canting, and the rear part of the bed, between the fast and loose heads, C, D is arranged to constitute an inclined grate *b*1 to direct the cuttings to the rear of the machine and cause the lubricant to be drained through such grate into a sump formed in the bed or legs which support same. The upper surface *a*1 of the carriage at each side of the cutting tool is also inclined to direct the cuttings and lubricant to the grate. The carriage is traversed along the bed by any suitable mechanism, and when provided with a rack-and-pinion feed a feature of the invention consists in arranging for the rack *a*4 to move with the carriage and the control or driving wheel *a*2 for actuating the pinion to occupy a permanent position at the front of the bed, about the centre of the traverse of the carriage. The rack occupies a position between the point of the cutting tool *a* and the centre of the guideway on the bed, so that all canting action of the carriage is eliminated to a minimum when the lathe is in use. To enable a long carriage to be employed, the fast and loose heads are offset so that the carriage can pass same, the rear portion of the carriage resting on a horizontal surface, which may be extended at the ends of the bed to support the fast and loose heads. (*Accepted December* 18, 1918.)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

120,770. Alldays and Onions Pneumatic Engineering Company, Limited, Birmingham, and A. Nicholson, Birmingham. Liquid Fuel Burners. (4 *Figs.*) November 21, 1917.—According to the invention, the adjustable nozzle, which is screwed on the front end of the outer tube, is provided on its conical interior surface with a series of screwlike vanes, the longitudinal edges of which vanes contact with the cylindrical inner tube of the burner or with a detachable mouthpiece on the said tube. The vanes may be integral with the adjustable nozzle or formed separate therefrom and attached thereto, the vanes constituting guides for the air under pressure as it passes to the mouth of the burner, and air being caused by its passage

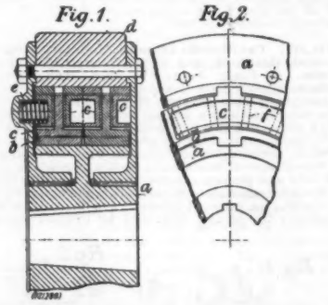
Fig.1. *Fig.2.*



between the vanes to perform a rapid rotary or whirling motion as it leaves the mouth of the burner, the oil spray issuing from the axial jet being caught in the whirling current of air and being thereby very efficiently atomised. *a* is the outer or air delivery tube of the burner, and *a*1 is the inner or liquid fuel delivery tube. *b* is the axial spindle by which the supply of liquid fuel is controlled, and *c* is the adjustable nozzle by which the air jet is controlled. In the nozzle *c* is the series of screwlike vanes *c*1, four being shown integral with the nozzle *c*. The inner tube *a*1 has a detachable mouthpiece *d*, cylindrical externally and conical internally, and having projections *d*1 which constitute supports for the spindle *b* near its free end. (*Accepted December* 4, 1918.)

121,228. J. Gardner, Patricroft. High-Speed Reciprocating Engines. (3 *Figs.*) February 18, 1918.—This invention relates to means for eliminating torsional vibration in the crankshafts of high-speed reciprocating engines. Such means usually comprise a multiple-plate type clutch by which a body of adequate moment of inertia is connected to the crankshaft so that the torsional vibrations are absorbed in the clutch. The invention comprises an improved arrangement of the clutch parts which gives high efficiency as a clutch for the desired purpose, and is capable of continuous use without its torsional vibration damping property becoming impaired. The hub *a* upon the crankshaft, which forms the driving element of the torsional vibration damper, has key grooves or slots therein, but the annular clutch members *b* driven thereby are of T, L, or approximately T or L-shape, in cross-section, the head part of the T or base of the L having

Fig.1. *Fig.2.*



keylike projections thereon for engaging the slots in the hub. The stem of the T or L forms the frictional driving portion for the rings *c*, which are of flat, channel or other shape, and are keyed to the flywheel rim *d*. Springs *e* bear upon the end ring or rings, or may enter the channels therein, for maintaining the rings and the interposed elements in driving contact. It will be understood that the annular elements or clutch members *b* and the friction rings or members *c* are free to slide with respect to the hub *a* and the flywheel rim *d*. The surface of each ring *c*, which contacts with an annular clutch member *b*, preferably has radial grooves *f* therein to prevent the formation between the clutch members *b* and the rings *c* of an unbroken film of lubricant of sufficient thickness to prevent an efficient driving connection between the parts. (*Accepted December* 18, 1918.)

The Dorr Thickener.—A description is given in *The Iron Age*, New York, of the Dorr thickener for utilising the waste water and the sludge from blast-furnace gas scrubbers. It is said to recover 95 per cent. of all ores carried in gas-scrubber discharge water, for recharging raw, mixed for sintering machines or made up in briquettes; it clarifies gas-scrubber discharge water so that it may be discharged into rivers, or be reused after cooling.